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DISKOGRAPHY IN ANKYLOSING SPONDYLITIS

by

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It has been generally considered that a feature typical of ankylosing spondylitis is the fact that the intervertebral disks remain normal. The same view is reflected in the roentgenologic and rheumatologic textbooks, such as those of SCHINTZ, COMROE and COPEMAN. In the latter's work we read as follows: "the intervertebral disks retain their normal thickness, a point of some importance in the differential diagnosis." Moreover, several authors, such as R. M. STECHER and H. HAUSER, J. SOLOVAY and C. GARDNER, hold that the disk spaces remain of constant width during the whole course of the disease.

However, in recent years it has been pointed out that the intervertebral space may diminish in ankylosing spondylitis. In 1949 R. MOWBRAY, A. L. LATNER and J. H. MIDDLENISS found narrowing of the disk space in 63 of their 137 cases and in 1951 C. M. GUEST and H. G. JAKOBSON in 19 out of 90 cases. In 1951 J. FORESTIER, F. JAQUELINE and J. ROTES-QUEROL demonstrated in their material that, of 200 cases, about 18 % showed narrowing of one or more intervertebral spaces. This finding was attributed either to Scheuermann's disease, to degeneration of the disk, or to the ankylosing spondylitis *per se*. Furthermore, three of their cases presented symptoms of a herniated disk in the form of monoradicular pain and underwent operation. However, no herniation was found at operation and the authors ascribed the monoradicular pain to a radiculitis caused by the inflammatory involvement of the intervertebral joints, L 5—S 1. The orthopaedic surgeon, A. KEY, in discussing the differential diagnosis of ankylosing spondylitis and disk lesions pointed out the importance of taking roentgenograms of the sacro-iliac joints because

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of the frequency with which they are involved in ankylosing spondylitis. Another point he made was that there should be a normal myelogram in this condition. However, he did not discuss the possibility that the two conditions might be present at the same time.

Own Material

In the course of the clinical and roentgenologic investigation of 110 male patients presenting objective signs of ankylosing spondylitis, 30 cases underwent diskographic examination. The study was prompted by many considerations. On comparing the roentgen films taken over a succession of years, we found that in several cases there was evidence of a progressive narrowing of one or more lumbar intervertebral spaces. On going through this material we found, moreover, some typical vertebral body alterations, which at the time diskography was commenced in October 1950, did not appear to have been referred to in the available literature. The changes seen in the vertebral bodies were those found with a true spondylitis, with destruction of the upper and lower margins of the anterior surface of one or more vertebral bodies at the border of the associated disk. C. M. GUEST and H. G. JAKOBSON in their article of May 1951 describe similar destructive changes "involving the adjacent surfaces of the anterior surface of the bodies of vertebrae in the lower dorsal region with peripheral eburnation and disk space narrowing, changes not unlike tuberculous spondylitis". These interesting spondylitic changes will be dealt with more closely when, in a subsequent article, we present our entire material. From the roentgenograms it seemed likely that the inflammatory process extended into the disk itself. Diskography therefore seemed suitable for studying the nature and type of the affection. The sort of clinical picture presented by a few of the cases gave us another reason for commencing diskography. One of us (ROMANUS) had found that pain occurring during the prespondylitic stage of ankylosing spondylitis was as a rule characterized by being centred in the gluteal region and radiating like an "atypical sciatica". This point has also been emphasized by a growing number of authors during the last few years. Cases 3 and 4 were selected for diskography chiefly on account of their somewhat atypical symptoms. The remaining 28 examinations were performed on patients who were undergoing check-up investigations and could be confined to bed for a few days in hospital. (We wish to thank Docent S. RÖDÉN, who gladly made it possible for us to study cases of ankylosing spondylitis in the Military Section, of the hospital.) The investigations were not carried out on ambulant patients. Following the puncture the patients remained in bed for 24 hours, and received chemotherapy and penicillin. One to three of the lower lumbar disks were studied.

The method worked out by K. LINDBLOM was used; very briefly, this involves the employment of a thin puncture needle inserted into the centre of the disk under fluoroscopic control. The needle passes from behind through the spinal canal. The contrast medium is injected, and any rupture or prolapse of a disk is visualised. Furthermore, if there be protrusion of a disk, this will be rendered greater by the injection of contrast so that any lumbago-sciatic symptoms will be exacerbated. This exacerbation of pain is typical of disk syndromes. We have made 74 diskograms without encountering complications in any case. In 39 of the 74 diskograms, the injected contrast was found distributed in a fashion which was considered typical for normal cases. That is, it was distributed bilocularly in the space normally surrounding the nucleus pulposus. The remaining 35 disks showed pathologic changes. The table lists the pathologic changes according to the particular disk involved. Thus we can see that the fifth lumbar disk is the one most frequently affected. This finding tallies closely with the results of the anatomic studies of K. LINDBLOM (1944). Among those patients with the pathologic diskograms, 6 merit special attention; in all these cases, the injection of contrast medium into the centre of one disk led to an exacerbation of the lumbago-sciatic symptoms already so familiar to the patient. This meant that they had or had had symptoms due to protrusion of this disk.

Table

Disk	Normal	Degenerated	Atypical changes	Total
L3—L4	14	2	1	17
L4—L5	15	11	2	28
L5—S1	10	16	3	29
Total	39	29	6	74

Case 1. V. ktr. 449. 16/1 1951. Male, aged 33, with symptoms typical of ankylosing spondylitis since 1945—1946. In 1949 he developed severe pain in the right lumbar region extending to the right thigh. Subsequently there were numerous exacerbations. The roentgen findings of ankylosing spondylitis at the time of diskography were still confined to the sacro-iliac joints. Diskography of the third lumbar disk provoked the right-sided pain. The disk was seen to have ruptured backwards and to the right towards the outer part of the intervertebral foramen and the contrast fluid followed the course of the third lumbar nerve somewhat downwards (Fig. 1 a—e). The patient became free from symptoms after conservative treatment.

Case 2. V. ktr. 516. 17/5 1951. Male, aged 30, with back pain dating from 1949. He was treated at the start with a plaster jacket, the diagnosis having been "insufficientia dorsi". He improved temporarily. The complaint returned in May 1951, when on roentgen examination changes typical of ankylosing spondylitis were stated to be present in the sacro-iliac joints. No involvement of the spinal column was observed. However, during diskography of the fourth lumbar disk, the patient noted moderate tenderness during the passage of the needle through the posterior longitudinal ligament. The injection of

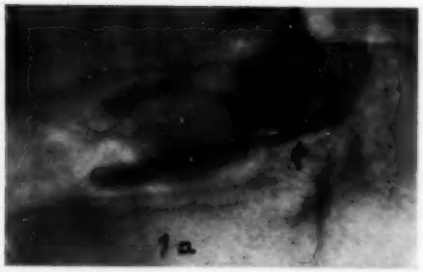

Fig. 1. a—c. Diskograms demonstrating the rupture and the leakage into the region of L3 with spread along the course of the third lumbar nerve. d—e. Drawings of the roentgenograms b—c.

the contrast medium elicited an already familiar sensation of discomfort and pressure with a certain amount of radiating pain at the level of the injection site. The films showed a rupture backwards involving the whole disk with epidural leakage of contrast fluid (Fig. 2 a—b). A period of rest after the diskography brought about a very temporary improvement. The treatment was subsequently discontinued.

Case 3. V. ktr. 432. 27/11 1950. Male, aged 35, with synostosis of the sacro-iliac joints together with typical, partly bridging, syndesmophytes in the thoracic spinal column. The disease had probably started with a short spell of pain sometime during his twenties. This phase was succeeded by a practically symptomfree interval of 5 years. After an accident, he experienced pain in the back for longer periods of time. Air myelography was performed twice with negative results, before the diagnosis of ankylosing spondylitis was finally made. Successive admission to hospital involved, among other things, roentgen treatment and massage, together with the wearing of a jacket. None of these measures resulted in any improvement worth mentioning. The patient was occasionally reduced to the condition of an invalid. From 1950 onwards the pain intensified, especially in association with movement of the trunk, when they were stabbing and accompanied by a feeling of numbness in the legs, particularly the right. Repeated roentgen examinations of the spinal column revealed that the fifth lumbar disk had been

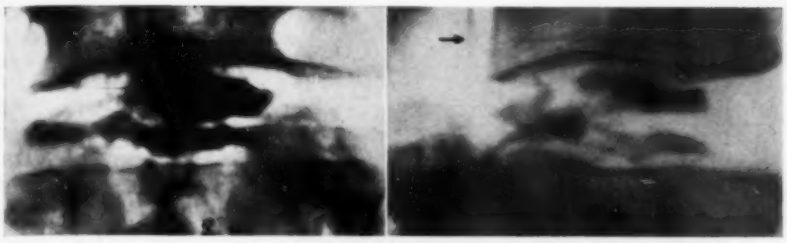

Fig. 2 a—b. Moderately degenerated disk ruptured backwards with extrusion of the medium into the epidural space.

Fig. 3 a—b. The intervertebral space is narrowed. The disk shows advanced degeneration and the posterior surface bulges backwards.

growing narrower over the period 1946—1947. Diskography provoked markedly the patient's right-sided lumbago-sciatic symptoms. Due to a technical mishap the pictures are not of a quality suitable for reproduction; they showed a greatly degenerated disk with suspected leakage of contrast fluid epidurally. The affected region was stabilized operatively by the creation of a synostosis between L 4 and S 1. The patient's symptoms were completely alleviated.

Case 4. V. ktr. 422. 7/11 1950. Male, aged 36, with spinal symptoms of the ankylosing spondylitis type since 1939. His back was becoming progressively more rigid. In the lower thoracic and upper lumbar regions of the spinal column there were typical syndesmophytes partly bridging the disk spaces. Since 1945 he has had occasional attacks of low back pain radiating into the right thigh; in May 1950 they were more persistent and severe. In October of the same year, the patient received roentgen treatment for the ankylosing spondylitis, following which, definite improvement occurred in so far as the greater part of the spinal column was concerned. However, the right-sided sciatica was unaffected. Roentgenograms of the spine showed that the fifth lumbar disk had narrowed somewhat between 1940 and 1950. During diskography of the fifth disk, the right-sided sciatica was greatly aggravated, and the films showed marked degeneration of this disk with total rupture backwards (Fig. 3 a—b). Conservative treatment included immobilization in a plaster jacket, with good effect.

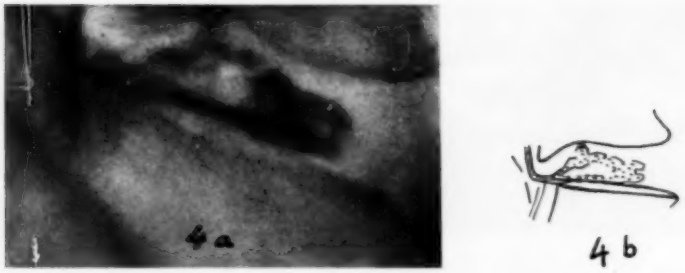

Fig. 4. a. The diskogram shows a disk ruptured backwards with leakage of the medium into the epidural space. b. Drawing of roentgenogram a.

Fig. 5 a—b. Rather advanced disk degeneration with ruptures in all directions. No extrusion of the medium into the epidural space; the posterior surface of the disk bulges backwards.

Case 5. V. ktr. 506. 30/4 1951. Male, aged 24 with occasional pains in the regions of the hip-joints and spine since 1941. There were long, symptom-free intervals. A roentgenogram in 1951 showed pronounced arthritis in both sacro-iliac joints with partial synostosis. The final roentgenologic examination on 17 March 1952 revealed what were suspected to be syndesmophytes, together with spondylitic changes in the bodies of the two lowermost thoracic vertebrae. This finding suggested that the process had not come to a standstill. During diskography of the fifth lumbar disk the patient experienced distinct discomfort during the passage of the needle through the posterior longitudinal ligament. In addition, the injection of the contrast medium provoked pain in the right gluteal region of a type familiar to the patient. Figure 4 a—c shows that the disk has ruptured backwards into the spinal canal and that there is an epidural leakage of contrast fluid.

Case 6. V. ktr. 569. 5/11 1951. Male, aged 31, had in 1943 an acute attack of lumbago. From 1947, he experienced pain in the lumbar region, this being of the type usually associated with ankylosing spondylitis. The range of movement of the back as a whole became successively more restricted. Roentgenogram of the spine revealed rather marked alterations of the ankylosing spondylitis type. During diskography of the fifth lumbar disk moderate pain was felt at the level of the site of injection. The films showed (fig. 5 a—b) that the disk had ruptured backwards towards the spinal canal. The posterior

surface of the disk clearly bulged backwards to a moderate extent, but there was no free passage of contrast fluid into the spinal canal. The patient became symptom-free after a period of rest together with roentgen therapy.

Discussion

As indicated by the table pathologic changes of a type not found in ordinary cases of disk rupture were present in six disks. In the anterior portion of three of these disks, the contrast at the site of the rupture entered irregular cavities situated in close proximity to the bone formation spanning the interval between two adjoining vertebral bodies. In the other three disks, similar, but less pronounced changes were observed. It is possible that the appearances, which were seen in five patients with advanced ankylosing spondylitis, reflect an inflammatory involvement of the disks, for the alterations in the latter seem to be associated with the spondylitic destruction of the adjoining borders of the vertebral bodies. These findings assist in an appreciation of the pathologic basis underlying ankylosing spondylitis. We shall return to this point in a subsequent article. Only the practical implications of our diskographic findings will be discussed now. Of the remaining 25 cases, in which 62 disks were investigated, 35 were found normal and 27 pathologic. Among 6 patients in whom 13 disks were punctured, no sign of degeneration was discovered, while each of 10 disks studied in 4 patients was found to have pathological changes. Of special interest were the 6 cases in which the injection of contrast served to reproduce the type of pain experienced earlier. If the pain provoked during diskography corresponded with that complained of earlier for varying periods of time, it was assumed that the chronic pain must have originated in the degenerated disk. From these disk studies we also learn that an ordinary disk rupture may co-exist with ankylosing spondylitis. Furthermore, we gather that this rupture is not unusual and may give rise to symptoms of lumbago-sciatica. The literature contains references to a raised protein content in the spinal fluid in certain cases of ankylosing spondylitis. This finding is held by many authors to indicate the presence of a radiculitis due to the involvement of the intervertebral joints, especially in the vicinity of L 5—S 1. Since S. Friberg and others have found a similar elevation of spinal protein content in disk rupture, the latter condition, in at least some of the ankylosing spondylitis cases, may well be the cause of the changes in the spinal fluid. The presence of a ruptured disk, giving rise to symptoms in a patient with ankylosing spondylitis, will greatly alter the treatment. This point is illustrated by our cases. The course taken by ankylosing spondylitis is often punctuated by more or less symptom-free intervals. It may be a ruptured disk which most troubles the patient and perhaps converts him almost into an invalid, as in case no. 3. Such cases require

treatment different from those having ankylosing spondylitis as the main feature. During the examination of all patients with ankylosing spondylitis complaining of pain more of the sciatic or lumbago type, the possibility of a concomitant disk protrusion has to be kept in mind. Therefore, in such cases, a careful history must be taken, a thorough physical examination made, and the pain assiduously analysed.

It has been pointed out previously that during the first, or sacro-iliac arthritis stage of ankylosing spondylitis, so called atypical sciatica may be a symptom. There is upper gluteal region pain radiating inferiorly and laterally for some distance along the back of the thigh and even reaching the knee. In our material, sciatica of this type was often present for a certain period of time on one side and then moved to the other. Occasionally, it shifted alternately from side to side, finally becoming bilateral. In cases of recurrent sciatica, therefore, one must watch for incipient ankylosing spondylitis and examine the sacro-iliac joints roentgenologically. Should the roentgenograms reveal sacro-iliac changes indicative of ankylosing spondylitis, the possibility of a concomitant herniation of a disk cannot be excluded. Since both conditions may be encountered together, the clinical methods of diagnosis must be improved and made more comprehensive.

SUMMARY

As disk space narrowing could be demonstrated in a series of 110 men with ankylosing spondylitis, diskography was performed on 30. 1 to 3 of the lower lumbar disks, amounting to 74 in all, were investigated; 39 were found to be normal and 35 pathologic. Of the latter, 6 presented appearances of an atypical rupture. In the remaining 29 disks, the "usual" pathologic disk changes of varying degree were found. In 6 patients a disk protrusion had given rise to symptoms reproducible on injection of the contrast medium. The practical significance of this possible finding from the point of view of treatment is stressed.

ZUSAMMENFASSUNG

Da in einer Serie von 110 Männern mit Spondylitis ankylopoetica eine Verengerung des Zwischenwirbelraumes gezeigt werden konnte, wurde bei 30 eine Diskographie ausgeführt. Eine, zwei oder drei der unteren Lendenzwischenwirbelscheiben, zusammen 74, wurden untersucht. 39 waren normal und 35 waren pathologisch verändret. Von den letzteren boten 6 Zeichen einer atypischen Ruptur. In den restlichen 25 Fällen wurden die „üblichen" pathologischen Zwischenwirbelscheibenveränderungen in wechselnder Ausbreitung gefunden. In 6 Fällen hatte eine Protrusion des Diskus Symptome hervorgerufen, die durch Injektion des Kontrastmittels reproduzierbar waren. Die praktische Bedeutung dieses eventuellen Befundes wird vom Gesichtspunkt der Behandlung stark hervorgehoben.

RÉSUMÉ

Une diminution de hauteur du disque a pu être mise en évidence sur une série de 110 hommes atteints de spondylarthrite ankylosante; la discographie a été pratiquée dans 30

cas; de un à trois disques lombaires inférieurs ont été examinés, soit 74 au total; 39 ont été trouvés normaux et 35 pathologiques. De ceux-ci, 6 présentaient des aspects de rupture atypique; les 29 autres montraient les altérations discales pathologiques «habituelles», à des degrés divers. Chez 6 malades, une hernie discale avait donné lieu à des symptômes reproductibles par l'injection de produit de contraste. Les auteurs soulignent l'importance pratique pour le traitement de ce symptôme possible.

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A NEW INSTRUMENT FOR URETHROCYSTOGRAPHY

by

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The method most commonly employed for the radiographic examination of the female bladder and urethra would appear to be that known as micturition urethrocystography, carried out after the bladder has been filled with a contrast medium by catheterization. The method gives a clear picture of any changes in the bladder, whether these be of an organic or functional nature. The micturition films also offer important information regarding the urethra such as its course and degree of dilatation, and the presence of the formation of valves, strictures, diverticula, etc. On the other hand, they do not give sufficient information about the mucosal pattern of the urethra — especially in its distal portion.

Urethrography by retrograde contrast filling is, however, regarded by many authors as being of less value than endoscopy. Whereas LOWSLEY and KIRWIN point out the importance of the urethrogram for demonstrating strictures, diverticula, suburethral abscesses and damage incurred in delivery, BRAASCH and EMMETT limit the value of the method to cases of diverticula. The latter also stress the difficulty of filling the urethra with contrast media; this question is almost certainly the main reason for the lack of interest in the retrograde method of examination.

It is, of course, often not possible to prevent leakage at the orifice of the urethra in injecting the contrast material, whether when using a syringe alone or one fitted with a rubber cone. There is thus always a risk that the urethra will not be completely filled, and the evaluation of the radiograph rendered difficult, or even impossible, by the leaking contrast medium entering the vagina or flowing over the skin. To prevent this leakage the instrument is often pressed up hard against the urethral orifice, causing a far from desirable shortening and deformation of the lumen.

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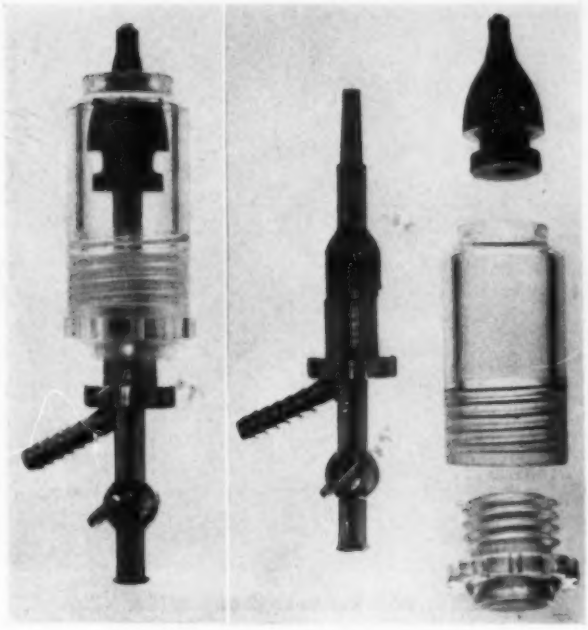


a. b.

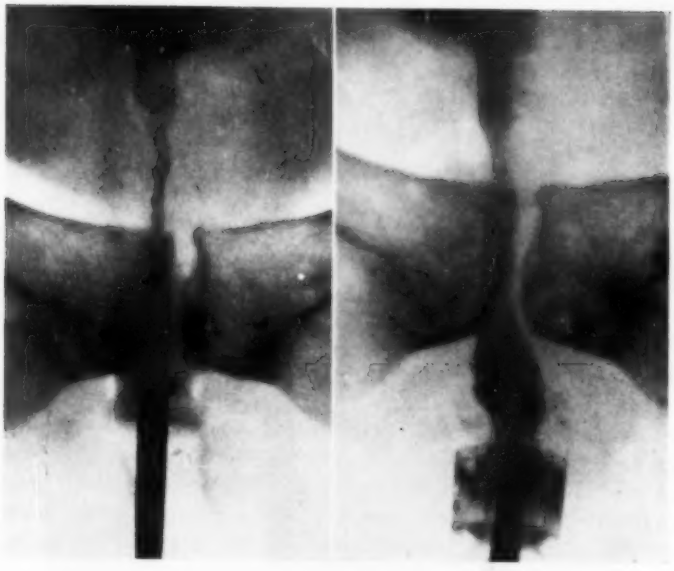
Fig. 1.

a) The instrument,
b) its four main parts: left, the cannula equipped with tap, connection for vacuum suction and expanding screw: right, the rubber olive and the two parts of the plastic bell.

Apart from these purely radiologic considerations, attention should be drawn to the discomfort and in many cases, pain caused to the patient by the procedure.

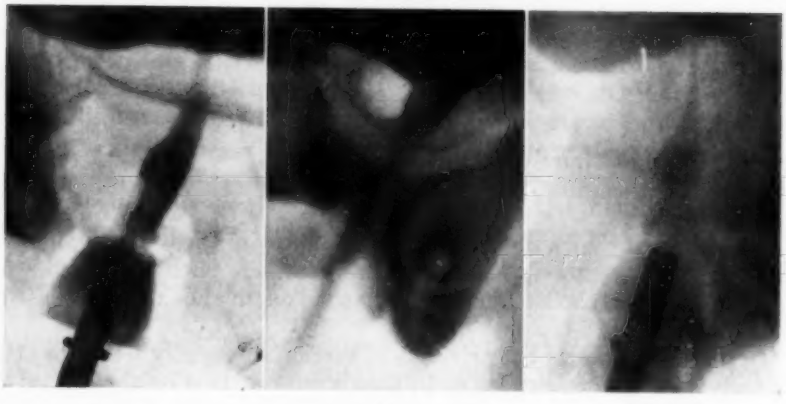
It is obvious that a device which will eliminate these disadvantages is called for. The anatomic conditions however, are such as to offer poor opportunities for fixation, so that any such contrivance must be based on an entirely new principle.

In the animal world the principle of suction frequently serves to attach the body to a smooth surface or to hold a quarry. It is on these lines that the instrument described has been devised (Fig. 1). It consists of a straight, in part double-barrelled, cannula of stainless steel, one end having a connection for a syringe and a tap. Near this end a short tube projects at an angle: the lumen of this tube emerges at the base of a rubber olive attached to the other end of the cannula. Both the cone and the orifice of the tube



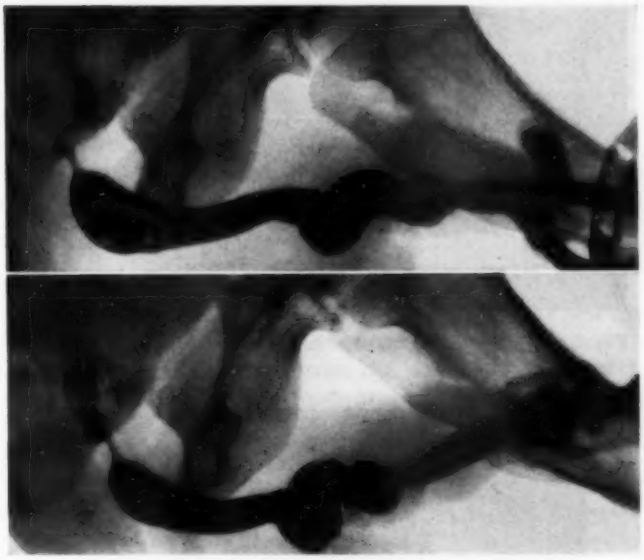
a. b.

Fig. 2.
a) 1950: with the method used earlier,
b) 1952: with the instrument described.



a. b. c.

Fig. 3. Comparison films of the urethra in the same case
a) with retrograde filling performed with the new instrument,
b) micturition film,
c) as (a) — lateral view.



a.

b.

Fig. 4. Urethrograms in the same patient
a) with Knutsson's instrument,
b) with the new instrument.
Patient treated with plastic surgery for post-traumatic stricture of the posterior part of the anterior urethra.

are enclosed in a two-piece bell of transparent acrylic plastic material. The instrument thus consists of four assembled parts each readily detachable.

The projecting tube is coupled to a water suction plant and the tip of the olive is introduced into the orifice of the urethra. The instrument will adhere to the surrounding mucous membrane once the movable plastic cap has been adjusted by means of an expanding screw which also closes the gap between the bell and the cannula. When a sufficient amount of soft tissue has been drawn up round the rubber cone, the latter should be pushed slightly forwards. The tissue will then act as a tampon and increase the effect of the suction.

A large number of experiments with this instrument has given only positive results. Not only has it been found to adhere so firmly that the patient herself could make any necessary movements with the instrument in position, but leakage, which previously had often caused interference, was entirely eliminated. The slight amounts of contrast medium, which in

Fig. 5. Urethrocystogram (new method) in a nine-year-old boy.

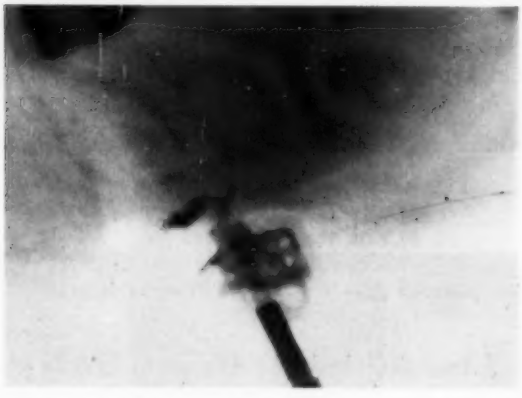


Fig. 6. Contrast filling (new method) of a small perineal fistula.

occasional cases seeped out around the olive due to its not having been pushed sufficiently forward, were immediately sucked away by the bell and had no adverse effect on the examination. As no pressure is exerted on the gland, the former almost inevitable shortening and deformation of the urethra is avoided. This is confirmed by the comparison films in Fig. 2. Furthermore, the satisfactory contrast filling of the distal portion of the urethra signifies that the retrograde method of filling may now be regarded as having, as far as the demonstration of the mucosal pattern is concerned, overcome the undeniable weakness of micturition urethrocystography (Fig. 3). A further important advantage of the suction instrument is that it in no way causes discomfort: no adverse effects have been observed

apart from occasional small, insignificant petechiae of the mucous membrane.

The instrument has proved equally satisfactory for urethrocystography in men. A clear representation of the anterior portion of the urethra is obtained. This region was frequently deformed by the earlier types of instrument which were clamped to the penis and pressed against the urethral orifice, and the films obscured by their metal parts (Fig. 4). Among the advantages of the method must be cited the fact that little discomfort is caused to the patient and that the examination may be performed with Markman's device for the distant manipulation of the contrast medium syringe. Furthermore, urethro-cavernous reflux which sometimes results from lesions of the mucous membrane caused by the instrumentation, should not occur. Although this complication is most undesirable, it has not been regarded as dangerous if a water-soluble contrast medium be employed. However, widespread urethral strictures which occurred in one case at Karolinska Sjukhuset, and which could with certainty be attributed to urethro-cavernous reflux, caused us to alter our opinion as to the alleged harmlessness of the phenomenon.

Finally, it should be mentioned that, by exchanging the front portion of the plastic bell for one with a smaller sucker, the instrument has proved successful for urethrocystography in children (Fig. 5). In one case of perineal fistula, which could not be outlined with contrast medium in the usual manner, the method also gave satisfactory results (Fig. 6).

As a heat-resistant plastic material is used in the manufacture, the instrument may be sterilised in the normal way by boiling.

The makers are A. B. Stille-Werner, Stockholm 4.

SUMMARY

A new instrument for use in urethrocystography, based on the principle of succion, is described. It may be employed equally satisfactorily in men, women or children.

ZUSAMMENFASSUNG

Ein neues Instrument zur Ausführung der Urethrozystographie wird beschrieben. Es ist auf dem Saugprinzip basiert. Es kann mit gleichem Vorteil bei Männern, Frauen und Kindern benutzt werden.

RÉSUMÉ

Description d'un nouvel instrument pour uréthro-cystographie, basé sur le principe de l'aspiration; on peut l'employer aussi bien chez l'homme que chez la femme ou l'enfant.

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INVESTIGATIONS ON THE OPTIMAL ILLUMINATION OF VIEWING CABINETS

by

Bjarne Merrild-Hansen and *Erling Ratjen*

Diagnostic radiology confronts its practitioners with two main tasks:
(a) the production of a technically satisfactory radiograph,
(b) its interpretation (if necessary in conjunction with fluoroscopy).

In this paper we shall deal with a common factor in the interpretation of the radiograph, namely the luminosity of the viewing cabinet. In outline it may be said that the reading of a roentgen film consists in appraising a visual impression. It is evident that a correct diagnosis is facilitated if the visual impression be an optimal one. Appraisal is a complicated, superior cerebral function which need not be discussed in detail.

Visual impression is based upon two fundamental qualities of the visual senses: 1) the power to apprehend light (or the contrast sensitivity), and 2) the resolving power of the eye. The third quality of the eye, the ability to appreciate colours, has up to now not been called much into play in this connection.

In ordinary diagnostic radiology (macro-roentgenology) the contrast sensitivity is of more importance than the resolving power of the eye, provided the brightness of the film be not too low. Of the compound functions of vision derived from the contrast sensitivity and the resolving power of the eye, the ability to estimate thicknesses of lines and vernier acuity (CLEMMESEN, 1944) are of special interest to radiologists.

Owing to the continuously and large output of processed films in the modern roentgen department, many different sizes and various degrees of density have to be put up in viewing boxes at the same time. The density (D) is $D = \log I_0/I$ (where I_0 is the intensity of the source of light and I the intensity immediately behind the film). For this reason many

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relatively clear and dark areas of the films will alternate. For a long time to come, we shall have to adhere to this method, even during a possible cinematographic era. Only in special circumstances will it be possible to select and stop down a certain area of the film for closer scrutiny.

It has been known for a long time that the contrast sensitivity of the eye decreases if the surrounding retinal areas be in an advanced state of irritation, a phenomenon called glare (physiologic glare, simultaneous contrast). In viewing roentgen films the glare may be caused as mentioned above, by defective shading of the film or by the highly translucent parts of the films (in roentgenograms of the lungs, heart, stomach etc.).

It may be presumed beforehand that the importance of defective shading is reduced on account of the variation of density in most films ($D_{max} \div D_{min}$).

If we limit ourselves to the contrast sensitivity we gather from Fig. 1 (after K. J. W. CRAIK, 1938) that as the brightness of the film becomes greater (abscissa I) the sensitivity of the eye increases (ordinate $\triangle$ I/I). Thus, when a brightness of between 10 and 15 foot-lambert or more has been reached we shall have attained optimal values (if the eye has been adapted to this illumination, and in the absence of glare). The differential sensitivity will then be about 2 per cent. Broadly speaking, the degree of density of most radiographs is about 1. Consequently, were it possible to ignore glare, a suitable viewing box might, for the time being, be rated theoretically at a minimum brightness of about 100—150 foot-lambert.

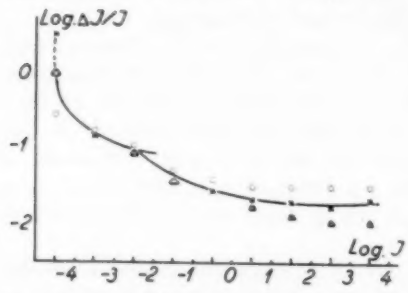

Fig. 1. Log $\triangle$ I/I is plotted against log I, using four subjects, so as to show the differential sensitivity when 'test' and 'adapt' illuminations are always equal. Test field 36° diameter. I $\geq$ 1.07 millilambert (K. T. W. CRAIK 1938).

Our investigations have been made with a somewhat primitive experimental arrangement. The advantage of this device, however, is that it corresponds exactly to the conditions under which practical diagnostic film interpretation takes place. Three viewing boxes were used, with a brightness of 50, 200, and 1,000 foot-lambert respectively. There was no other illumination of the room other than that coming from the boxes. The walls were light in colour so that filing, secretarial work, and the examination of case records were carried out comfortably and easily. Four observers aged between 27 and 35 were placed at a constant distance (50 cm) from a test film.

In our experiments we have used aluminium foil and films without intensifying screens. A radiograph of ten sections of circular aluminium foils each consisting of from 1 to 10 layers of foil, made a so-called 'bottom-plate'. In the middle of the film an area was left un-blackened, forming a 'glare area'. Further, we employed circular images of aluminium foil, likewise consisting of 10 sections of from 1 to 10 layers of foil. Some of the film sections were provided with 'holes' and others with 'dots', made by punching out the aluminium sections and, by affixing small foil discs of the size of the holes, respectively. A space left unblackened in the middle of these provided a 'glare area'. By placing one of these films on top of the 'bottom-plate' and turning it round a central axis it was possible to vary the blackening of the dots as well as the holes, and of the surroundings of both. Thus, either a uniformly dark area surrounded by different homogeneous and more translucent parts of film, or a uniform easily translucent area surrounded by different sector-shaped, homogeneous, darker fields was obtained.

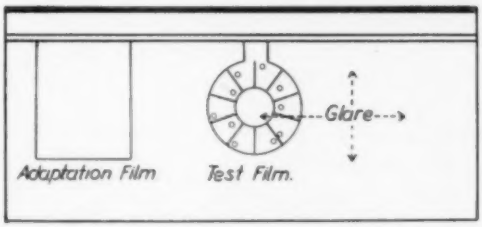

Fig. 2. Front of viewing box. Density of adapting film: 0.5.

The density of the dots varied from 0.73 to 1.7, and that of the holes from 0.85 to 1.82. The difference in density between the dot or hole and their surroundings varied between 0.015 and 0.075. The average density of the field varied between 0.75 and 1.8.

The test field is viewed binocularly. It is covered in such a way that only one sector is visible at a time. The position of the dot varies from field to field. It is therefore necessary to scan the whole of the field if the dot be inconspicuous. While the test field is changed the subject views a 24×30 cm film with a homogeneous degree of density of 0.5. The field measures $8° \times 5° 45'$. The dot which is strictly delimited: 41′. The exchangeable glare area, the brightness of which is very near to that of the viewing box, measures: $4° 36' \times 2° 50'$, and its average distance from the dot is $2° 30'$. The extremes of the test field, outside of which the brightness of the viewing box is kept, are on an average $6° 20'$ from the dot. The time it takes to point out the dot is registered by means of a stop watch.

We selected a number of films from our records, pre-eminently such as had given rise to diagnostic difficulties owing to slight differences of contrast.

All measurements were made by means of a densitometer placed at our disposal by courtesy of the *Berlingske Tidende*. The brightness and

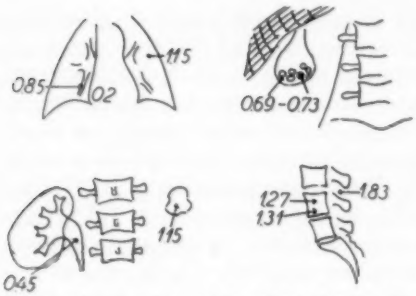

Fig. 3. Figures of density obtained by measurement on films frequently met with in diagnostic radiology.

illumination of the viewing boxes were examined by means of an exposure photometer manufactured by *Salford Electrical Instruments Ltd*, and placed at our disposal by courtesy of *Ilford Ltd.*, Copenhagen. Both these instruments have been found capable of measuring areas of a diameter of two millimeters. They are easily operated and quite indispensable for our purpose.

Results

It soon became evident that despite our efforts to obtain test films with slight differences of contrast, the enormous adaptibility of the eye had the effect that only a few dots escaped detection. Numerical calculation of the viewing time gave an expression of the visual performance.

We selected a few examples which are presented graphically. The difference in degree of blackening was plotted against the visual function in terms of the reciprocal value of the average figure representing the viewing time required in a number of individual observations. 100 means that the dot was pointed out in 1 second. The results obtained by each individual subject did not vary much.

Glare does not reduce the visual function in viewing roentgen films when complete shading of the film cannot be effected. Dim illumination in the viewing box proved unsuitable for fairly dense films (Fig. 4).

With sufficient illumination, dense films may be also interpreted and glare need not be feared even with 1,000 foot-lambert (Fig. 5).

It serves no purpose to stipulate a value for the brightness of viewing boxes if data on the illumination of the room as a whole, be lacking.

Fig. 6 shows the difference in the visual performance when the illumination of the room is increased. The dotted curve shows what happens when the illumination of the room is increased from 6 to about 150 foot-lambert measured by reflection from white paper.

We endeavoured to maintain a constant relationship between the conditions of adaptation and the brightness of the viewing box. Of course, it must be borne in mind that adaptation within the range of brightness concerned takes place quickly, presumably in seconds (EDMUND, 1924, FRANDSEN, 1924, CRAWFORD, 1937). Fig. 7 however, shows the signifi-

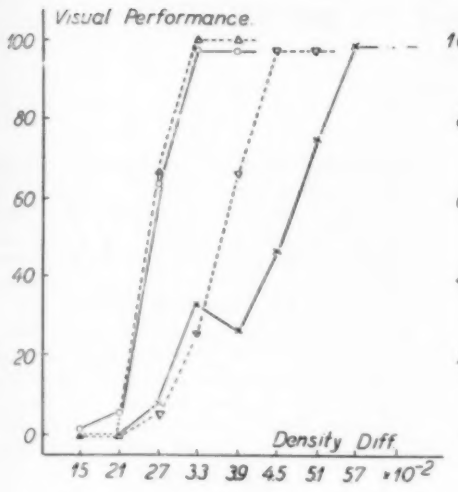

Fig. 4.

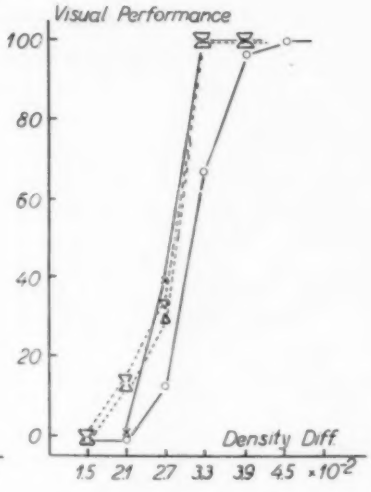

Fig. 5.

Fig. 4. Modified FORSSELL viewing box of brightness 50 foot-lambert. Visual performance tested.

Curve — — — △ — — — and — — — o — — — middle film-density 1.1.
Curve — — — ▽ — — — and — — — x — — — middle film-density 1.7.
Curve — — — △ — — — and — — — v — — — with central glare.
Curve — — — o — — — and — — — x — — — without central glare.

Fig. 5. Visual performance tested with a viewing box of brightness 1,000 foot-lambert. Terms and markings as in Fig. 4.

cance of the adaptation condition of the eye to the differential sensitivity (CRAIK, 1938).

When not viewing films the eye will, in practice, be fixed upon subjects of greater brightness (case records, papers etc.).

Discussion

The FORSSELL viewing box appeared before the advent of the double-coated film. When the latter came to the fore the degree of blackening could be increased from 1.5 to about 3.0, and the gradation increased. As early as 1927, BRONKHORST maintained that most viewing lanterns were too dim, even for single emulsion films. CHANTRAINE (1935) was of the same opinion, and SPIEGLER proposed a viewing box with a powerful built-in spotlight, the position of which could be varied behind the surface of the glass.

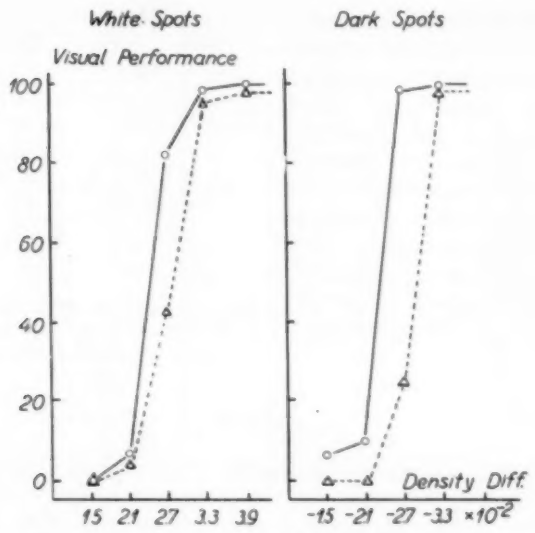

Fig. 6. Visual performance and additional illumination of the room (150 foot-lambert-reflected from white paper).

SPIEGLER did not consider that it would be advantageous simply to increase the brightness of the lantern, as this would also increase the risk of glare. In 1936 he proved, by means of experiments, the deteriorating effect of glare on contract sensitivity. SPIEGLER, however, worked with well-exposed films with a density of about and above 2, being an ardent advocate of a more rational utilization of the rectilinear steep part of the gradation curve. In his opinion a film of a density of about and below 1 must be considered poor. From a photographic point of view they are considered underexposed, SPIEGLER (1937).

A few years ago BRONKHORST, TEN DOESSHATE, and FISCHER (1948) dealt with the ophthalmic-physiologic basis of film-viewing. The practical result was their suggestion of a brightness of from 200 to 1,000 foot-lambert, with a density of about 1.5.

Our experimental results support the viewpoint of BRONKHORST et al., and in our opinion the glare does not play any essential part at these levels of brightness and degrees of blackening.

Some comment on the brightness of the viewing boxes which we advocate (200 to 1,000 foot-lambert under an additional room-illumination of about 10 foot-lambert) should perhaps be made. The viewing of films is a visual effort often prolonged and concentrated so that the observer

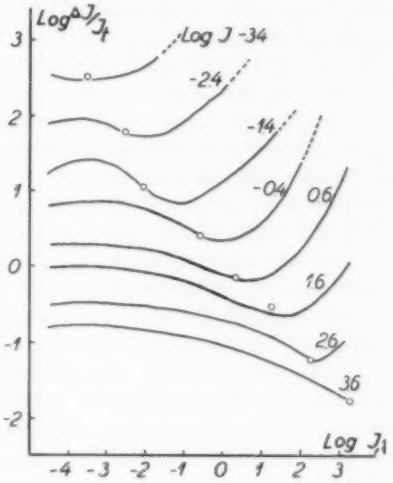

Fig. 7. Influence of the level of adaptation of the eye on the contrast sensitivity. Test field = 36°. Ordinate: I/I_{test} for $I/_{test}$ = — 3.6. 2.6 — — —, respectively, reading upwards. Equal 'test' and 'adapt' illuminations indicated by circles round certain points (K. T. W. Craik, 1938).

All curves above the lowest are moved upwards successively by 0.5 on the ordinate scale to avoid confusion. True ordinate values of each may thus be read by subtracting 0 from the ordinates of the lowest curve, 0.5 from those of the second curve &c.

tires. In an interesting investigation Simonsen and Brozek (1948) showed that after visual work of prolonged duration (2—4 hours) it is possible by a series of complicated tests to prove a reduction of the visual function. The reduction depends upon the illumination during the work. In our experiments, which seldom lasted for more than $1^1/_2$ hours, we found only a slight difference in the visual function at different levels of brightness. By considerably extending the test period, however, it

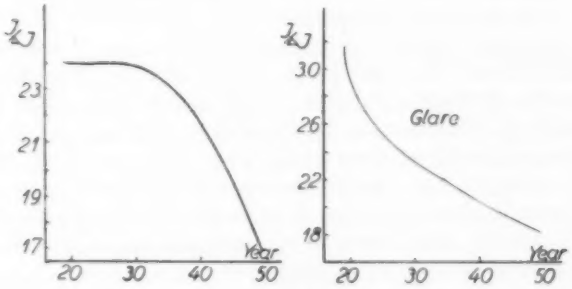

Fig. 8.

Left: Average contrast sensitivity as a function of age, measured at a degree of brightness of 0.3 candle/square meter, without glare.

Right: Average contrast sensitivity as a function of age, measured at a degree of brightness of 0.3 candle/square meter, with glare. In the older age group, glare causes a much greater decrease in sensitivity to contrast. (Both from Bouma, 1947.)

may be possible to demonstrate differences and to determine an optimal value of brightness. In our daily routine, we gained the impression that degrees of brightness below 200 foot-lambert made the easy and rapid reading of films difficult. Our subjects were 27 to 35 years of age; at more advanced ages a more intense illumination is required for the same visual work. WESTON (1948) stated that between the ages of 40—50, the ability of those with normal vision to perform detailed 'close up' visual work decreases by about 5 per cent per annum. Moreover, he found that by increasing the illumination it was possible to improve the performance of 47-year-old observers by 400 per cent, while those aged 24 could be improved by only 18 per cent.

On the other hand, the improvement to be expected from the use of increased illumination may be counteracted in the older group of subjects by glare. While this phenomenon hardly plays any part in early middle life, Fig. 8 seems to imply that for the older group it may be of considerable importance, BOUMA (1947). We have had no opportunity of studying this aspect.

We have three sources of uncoloured light at our disposal

(1) daylight,
(2) incandescent lamps,
(3) fluorescent tubes.

In attempting to obtain stable, possibly standardised, viewing conditions (see 'Recommendations for the Standardisation of Radiographs in Industrial Pulmonary Diseases', Brit. J. Radiol. 33 (1950), 500) daylight need not be considered (BALLENGER, et alii, 1932); the opal or frosted film (BONNEFOY, SCHLEUSSNER, 1930) is of historical interest only.

The use of *incandescent lamps* has three drawbacks: The difficulty in providing a viewing surface of uniform brightness, the heavy wattage and the troublesome heat production. It may be counted among the numerous merits of GÖSTA FORSSELL that as early as 1908 he proposed the use of indirect illumination by incandescent lamps of polished plate glass upon which the films were hung. The white parabolic reflector was simple, and for many years most roentgen departments were fitted with GÖSTA FORSSELL's viewing boxes. The heat may be eliminated, at least partly, by providing circulation of air around the lamps (WERTHEIMER, 1931) or by means of a water filtration.

At this point it may be mentioned that ultra-violet rays have also been used. In the *Auroscope* the invisible rays from in front after passing through the film are transformed into light by means of a fluorescent ZnS reflector situated behind the film. This light reaches the viewer by being reflected through the film, the gradation which apparently increases during this double passage. This method is particularly fitted for under-

exposed films, but is inapplicable for films of high density. It is also unsuitable for mass demonstrations. The brightness has not been stated (BERTHOLD and RIEHL (1936), LEWIN (1936)). HASCHÉ (1935) seem to have been the first to use an Hg vapour tube in place of incandescent light. It was of 760 watts, the illumination indirect and the brightness of the 1.25 sq.m viewing surface 300—800 foot-lambert. As time went by and more and more hospitals were built, the authorities came to realise the importance of adequate and improved facilities for viewing, and the fluorescent tube came into common use. In comparison with the incandescent lamp, it represents a combination of great efficiency and a relatively small brightness of surface (H. C. WESTON, 1947). Consequently, it has less glaring effect and may be used as a direct illuminator in viewing boxes. It is easy to obtain a uniform luminosity by inserting a plate of opal glass — unfortunately rather expensive — between the tube and the film. By arranging phase shift between the tubes, stroboscopic effect is minimised; the flicker is due to the fact that, in contrast to the filament, the gas column in the fluorescent tube becomes relatively cold between the voltage impulses. If, according to HASCHÉ, we express the efficiency (N) of a viewing box by:

$$N = \frac{\text{brightness (in foot-lambert)} \times \text{size (in M}^2\text{)}}{\text{consumption (in watts)}}$$

we obtain for our modified FORSSELL box:

$N = \frac{50 \times 1}{1{,}200} = 0.042$; and for our new double-sided box with fluorescent tubes:

$N = \frac{200 \times 2}{200} = 2$. This difference (about $\times$ 50) is sufficient to demand the use of fluorescent tubes for economic reasons. To this may be added that the production of heat is so slight as to be disregarded. The type of tube in most common use is 120 cm long and consumes 40 watts. The brightness of the naked tube is about 1,000 foot-lambert. We have made an experimental viewing box with the same efficiency as the above and a brightness of 500 foot-lambert.

The total saving in current consumption will be less marked of course, if the viewing boxes are fitted with changeable filmframes (BAASTRUP, 1937, RUNSTRÖM, 1947).

Fluorescent tubes, the intensity of brightness of which may be controlled, have been placed recently on the market.

As mentioned above, the brightness of the fluorescent tubes employed by us is about 1,000 foot-lambert. The length of the tube is 120 cm but

the effective length of high uniform brightness is only about 113 cm. If the distance between the individual tubes and between them and the opal glass plate be halved to about 9 cm, the brightness of the viewing box will increase from 200 to 500 foot-lambert. Tubes of a length of 150 cm and of 80 watts do not seem to offer any advantage, as no difference in brightness was detected by our exposure photometer. On the other hand, long slender fluorescent tubes ('slim line') 240 cm in length and 26 mm in diameter are now available. They operate at a voltage of 750, the luminous power being evenly variable. Experiments have shown that at 150 watts the brightness is twice that of a 40 watt tube. Consequently, it is possible to produce a convenient source of light in the comparatively rare cases where 200—300 foot-lambert are considered insufficient, particularly as the tubes may be bent as desired.

Our investigations were concerned only with uncoloured light. It soon became evident that a decision as to whether any given wavelength was preferable or any wavelength was to be avoided in a viewing box, presupposed a complicated and technically exacting series of fundamental ophthalmo-physiologic experiments. A survey of the literature, however, provided certain indications.

If we consider the curve representing the sensitivity of the light-adapted eye, at different values for λ, we find that the maximum is about 0.540 my to 0.560 my (yellow-green). Consequently, if it were equally easy to produce all wavelengths, yellow-green might be considered the most appropriate.

The differential sensitivity of the eye, in various parts of the spectrum, is a matter about which something is known.

HECHT, PESKIN and PATT (1937) state that the variation is slight. L. C. THOMSON (1949) who is supposed to have most experience in this field, has reported only a small difference in the ability to discriminate throughout the spectrum at a given degree of brightness. A study of his curves, however, indicates that what Thomson calls 'small' may be of importance although it seems hardly worth while to make calculations on the basis of these curves. They are founded upon measurements upon the darkness-adapted eye. HENDLEY (1948) found the same differential sensitivity to white and red at different degrees of brightness.

It is known that glare is dependent on λ. IVANOFF (1947) proved that blue light produces the strongest glare, then follows green, red, white, and yellow. The effect of glaring light is greatest upon a blue test field, less marked upon a red, green, or yellow. KATZ (1949) too, found that orange-coloured light (0.640 my) resulted in the smallest amount of glare. The fact that the velocity of vision of the light-adapted eye is most marked with yellow and red (less than 1/200 second) and less marked with blue (1/10 second), (BYRN, 1946), is of no definite impor-

tance, the duration of the visual impression being of quite another order of magnitude when it is a question of viewing of films.

The lack of physiologic experience within our special field is also reflected in the radiologic literature. Practically speaking, it is possible to find advocates for almost any colour. COURCOUX and GIBSON (1926) prefer green for films of slight density and very slight contrast, and yellow for films with heavy blackening. HENIUS (1926) and ERDÉLYI (1929) also preferred green light for under-exposed films. JORDAN (1938) was unable to find any difference in the minimum contrast sensitivity in experiments on white and blue films. Finally, DE GRAAF (1938) was of opinion that yellow sodium vapour light was best suited for viewing boxes. Studying soft-tissue roentgenography, that is films with relatively slight contrast, CARTY (1938) emphasized the importance of using different coloured light. Apart from stating that this subtlety was necessary, he made no concrete suggestions. BRONKHORST, DOESSHATE, and FISCHER (1948) after reviewing a great amount of literature, maintained that the basis for preferring a certain colour was so slight that white must be preferred.

Several research workers consider a change in the wavelength of the light during viewing unfortunate, and advise against using a rheostat for the control of the intensity. A reduction of the luminous power is said to be accompanied by a change in quality towards the reddish-yellow. By inserting some moveable louvre-like shades in front of the source of light it is possible to make a selective change in the intensity (MONTGOMERY, 1932; FEREE and RAND, 1939). The difficulty is increased as the grained film can hardly be said to act as a simple grey filter; but investigations are required regarding the dispersion and absorption in exposed film.

This discussion on the importance of colour cannot be ended without it being mentioned that in the course of time endeavours have been made to replace the contrast which is a consequence of variations in the degree of density, by different colours in the film emulsion. During the early years, these experiments were on a line with the efforts to intensify a film of only slight contrast by means of precipitations on the Ag^{+} grain of, for instance, uranium salts (GÖSTA FORSSELL, 1910) or Ba^{++} (BELLUCI, 1927). AREND (1934) mentions an example in which, after tinting a film of the femoral condyle, it was possible to outline a cyst which, on the plain film, could not be seen. Time has afforded such a great improvement in the visible contrast on the black and white film, that interest has slackened. Recently, however, it was revived by DONOVAN (1951) who showed new ways of making roentgen films in colours, although, as he himself said, 'the technique is still in its infancy'.

SUMMARY

A survey of the principles and the physiologic basis for the viewing of roentgen films is given. As far as may be gathered from the literature, no special colour of light is to be preferred. On the basis of experiments on test films, the authors suggest a viewing box brightness of about 200—1,000 foot-lambert. Glare is of no practical importance in the younger age groups. The risk of an erroneous diagnosis is considered greater with a dim than a strong light. For the time being, fluorescent tubes are considered the most suitable sources of light.

ZUSAMMENFASSUNG

Es wird ein Überblick über die Prinzipien und die physiologischen Grundlagen für die Betrachtung von Röntgenfilmen gegeben. Soweit man aus der Literatur ersehen kann, ist keine spezielle Lichtfarbe zu bevorzugen. Auf Grund von Experimenten mit Versuchsfilmen schlagen die Verfasser eine Schaukastenlichtstärke von etwa 200—1,000 „foot-lambert" vor. Das blendende Licht hat in den jüngeren Altersgruppen keine praktische Bedeutung. Das Risiko, eine fehlerhafte Diagnose zu stellen, ist, wie man meint, grösser bei mattem als bei starkem Licht. Im Augenblick werden fluoreszierende Röhren als zweckmässigste Lichtquellen angesehen.

RÉSUMÉ

Les auteurs rappellent les principes et les bases physiologiques de la lecture des films radiographiques. De la littérature, on peut conclure qu'il n'y a pas de couleur spéciale de la lumière qu'on doive préférer. Se basant sur une expérimentation avec des films étalons, les auteurs proposent une brillance de négatoscope d'environ 200—1,000 foot-lambert. L'éblouissement n'a pas d'importance pratique pour les sujets jeunes. Le risque de commettre une erreur de diagnostic est considéré comme plus grand avec une lumière faible qu'avec une lumière forte. A l'heure actuelle les tubes fluorescents constituent la source de lumière la plus appropriée.

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FROM THE TUBERCULOSIS SERVICE (DIRECTOR: PROFESSOR ALEJANDRO CELIS), GENERAL HOSPITAL, MEXICO, D. F., MEXICO

LYMPHATICS OF THE THORAX

AN ANATOMIC AND RADIOLOGIC STUDY

(Preliminary Report)

by

Alejandro Celis and *José Kuthy Porter*

At the present time most of the structures contained in the thoracic cavity may be demonstrated; bronchography enables us to study the bronchial system, while angiography makes visualization of much of the blood vascular system possible. However, up to the present, no roentgenologic methods which will outline the pulmonary lymphatic system or the bronchial arteries are known.

Our purpose in initiating this study, was to find a means of rendering the lymphatics of the thorax opaque; for this purpose an anatomic and radiologic study was carried out in fifty human cadavers.

The lymphatic vessels were first observed by ERASISTRATUS (280 B. C.) and studied by GALEN. But it was not until 1622 when ASELLI found the vessels in a living dog and had shown by cutting into them that they were not nerves, that it was essentially a new and great discovery. In 1570, many years before the physiologic observations of ASELLI, EUSTACHIUS (1) described the main trunk of the lymphatic system.

The connection between the lymphatic vessels in the mesentery, observed by ASELLI and the thoracic duct studied by EUSTACHIUS, was demonstrated by PECQUET, who, in 1651, also described the cisterna chyli. The ramifications of these main trunks was followed out by skilful injections and the results of the studies presented in large folios by MASCAGNI (1787) and SAPPEY (1874) (2). The lymphatics of the lungs were first described by RUDBECK (3) in 1653.

Submitted for publication, March 26, 1952.

Anatomy of the Pulmonary Lymphatics

Theoretical Considerations

There is a very large literature upon the anatomy of the pulmonary lymphatic system. It has been the object of research by: HUNTER (1874), VYVODTJEW (1865), SIKORSKY (1870), SAPPEY (1874), SHIMASUKI (1931), TORII (1934), LUNA (1934), KUTZUNA and IVANOV (1936), MILLER, WARREN, DRINKER and many others. The subject still remains, however, a controversial one. There now appears at any rate to be general agreement that the lymphatics of the lungs consist of a branched arrangement of closed vessels not in open communication with the pulmonary tissue nor the pleural cavity.

MILLER (4) has pointed out that the lungs are more extensively supplied wity lymphatics than the kidneys, liver or spleen.

The walls of the lymphatic vessels of the lungs are decidedly thinner than those of blood vessels of the same caliber; in the larger ones, the endothelium with the underlying connective tissue forms a tunica intima. These lymphatics are often composed of three coats of loose texture. The media contains circular smooth muscle fibres and a small amount of elastic tissue; the externa is composed of longitudinal connective tissue and scattered bundles of longitudinal muscle fibres.

The lymphatics of the lung may be divided roughly into two plexuses, a superficial and a deep; the first lies beneath the pulmonary pleura while the second is associated with the branches of the pulmonary vessels and the ramifications of the bronchi. There are anastomoses between the superficial and deep lymphatics of the lung in the pleura and in the region of the hilum, which is the site of a group of lymph nodes.

In the case of the larger bronchi, the deep plexus consists of two networks, one beneath the mucous membrane and the other surrounding the walls with an anastomosis between the two. In the smaller bronchi there is only one plexus and this extends as far as the bronchioles. Histologic observations have shown that the lymphatic capillaries do not surround the alveoli; their terminal saccular radicles end just short of the atria around the alveolar ducts and thus before the margins of the largest mass of respiratory lung tissue (5).

The branches of the pulmonary artery have two or three accompanying main trunks of lymphatics which anastomose with the bronchial plexus. The smaller branches of the pulmonary veins bear one or two lymphatic capillaries, while the larger ones are surrounded by a rich network.

The lymphatics which connect the superficial and deep plexuses have valves which open towards the hilum of the lung; there are but few valves in the region of the hilum in the deep plexus of lymphatics.

Only a single plexus of lymphatics exists in the pleura, though a pleural and a subpleural plexus have been described. The pleural lymphatics are arranged in the form of irregular polyhedral rings and in general they are larger than those of the deep plexus.

Direction of the Lymph Flow

It is not possible as yet to describe the lymph circulation in the lung precisely as the blood circulation. Apparently there are valves in the hilar region in the superficial plexus of lymphatics and at the point of junction between these and the deep set. Within the lung there are no valves.

The flow in the bronchial and arterial lymphatics seems to be towards the interior of the lung, while the lymphatics which accompany the pulmonary vein and its branches, except in the narrow zone situated just beneath the pleura, drain towards the hilum and are provided with valves which open inwards toward the hilum, showing that the lymph flow is central-wards. The lymphatics situated in the septa marking out the secondary lobules, are provided with valves which open outwards toward the pleura.

The rich network of lymphatics in the pleura are provided with valves which open in all directions, allowing a free circulation of the lymph within the limits of the pleura; they eventually unite to form main trunks which, together with the lymphatics coming from the interior of the lung along the pulmonary veins, enter the tracheo-bronchial lymph nodes. It is at the hilum of the lung where the largest collections of pulmonary lymph nodes are encountered; in this region one would expect to find radicles draining into the thoracic duct, so that there should be the freest possible movement of lymph toward the great veins. But as a rule, no such arrangement exists; according to DRINKER (5), all the lymph from the right and left lungs, except for a small area at the left apex, drains via the right lymphatic duct into the right subclavian vein.

The thoracic duct.

The thoracic duct in the adult varies in length from 38 to 45 cms and extends from the second lumbar vertebra, where it forms a triangular dilatation known as the cisterna chyli, to the root of the neck. It enters the thorax through the aortic hiatus of the diaphragm and ascends through the posterior mediastinum between the aorta and azygos vein. At about the level of the fifth thoracic vertebra, it inclines towards the left side, enters the superior mediastinum and ascends behind the aortic arch and the thoracic part of the left subclavian artery, between the left side of the esophagus and the left pleura, to the upper orifice of the thorax. Passing into the neck, it forms an arch which rises about 3 or 4 cms above the clavicle and crosses anterior to the subclavian artery, vertebral

vessels and thyrocervical lymph trunk or its branches and ends by opening into the angle of the junction of the left subclavian vein with the left internal jugular vein.

In structure the thoracic duct resembles a vein, its wall being made up of three layers, a tunica intima, a tunica media and a tunica adventitia. At its commencement it is about equal in diameter to a goosequill, diminishing at about the middle of the thorax and again becoming dilated just before its termination. It is generally flexuous and constricted at intervals so as to present a varicose appearance. Sometimes it divides into two vessels of unequal size which soon reunite, or into several branches which form a flexiform arrangement.

The thoracic duct, as all larger lymphatic vessels, possesses valves, but the number of such valves is neither constant nor definite; at its termination it is always provided with two which prevent the passage of venous blood into the duct.

The cisterna chyli receives the intestinal and the two lumbar lymphatic trunks. On either side, opening into the cisterna chyli or the commencement of the thoracic duct, is a descending trunk from the posterior intercostal lymph nodes of the lower six to eight intercostal spaces. In the thoracic cavity, the duct is joined, again on either side, by the draining trunks of the upper lumbar lymph nodes. It also receives the efferents from the posterior mediastinal lymph glands and from the posterior intercostal lymph nodes of the upper left intercostal spaces.

In the neck the duct collects the left jugular and left subclavian trunks and occasionally the left bronchomediastinal trunk (6, 7).

Material and Method

Our purpose in initiating the current investigation was to study the lymphatic system of the thorax, both in the normal subject and in pathologic cases mainly with pulmonary diseases.

We divided it into several parts in accordance with the anatomic and functional principles involved.

I. Study of the thoracic duct in the human cadaver:
   a) Dissection of the thoracic duct.
   b) Injection of a dye into the thoracic duct followed by dissection.
   c) Rendering the thoracic duct radio-opaque by the injection of contrast medium in the direction of the lymph flow.
   d) Rendering the thoracic duct radio-opaque by the injection of contrast medium against the direction of the lymph flow.

II. Study of the thoracic duct in the dog.

In this report we shall not discuss the study that is being made on the thoracic duct and right duct in dogs, in as much as the number of our cases does not permit of conclusive evidence. We only want to mention the fact that the investigation is being made, following the same methods outlined.

In the first three of the fifty cadavers examined, we began our study by dissecting the thoracic duct in the neck; even though a careful dissection was made at the angle of the junction of the left subclavian vein with the left internal jugular vein, we were not able to find the duct. A left thoracotomy by removal of the ninth rib was performed in a further five bodies. The aorta was then dissected and pulled forwards by which approach we were able to identify the thoracic duct in most cases; in some, we injected a dye and followed the dissection upwards into the neck as far as the termination of the duct.

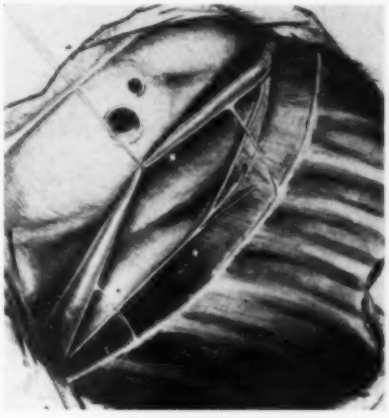

Fig. 1. Drawing depicting the thoracic duct giving off two branches. (Aorta pulled forwards.)

In the next eleven cadavers the thoracic duct was carefully dissected from the diaphragm up to the upper part of the thorax, and its course, relations, ramifications and branches studied; in three instances pneumonectomy was previously carried out in order to have a clearer field so that diagrams and drawings (Fig. 1) could be obtained.

In most of the cases we found a single trunk of very variable diameter, tortuous and constricted at intervals, ascending through the posterior mediastinum behind the esophagus between the aorta and azygos veins. In two cases we observed that the thoracic duct divided into two vessels of about the same size and which reunited at about the level of the fourth thoracic vertebra. In three cases we found several trunks opening into the thoracic duct at the level of the aortic hiatus of the diaphragm. In two cases we encountered a branch communicating with a plexus of lymphatics around the aorta at about the level of the seventh and of the eighth thoracic vertebrae respectively. In two cases a branch was found connecting with a small plexus of lymphatic capillaries which surrounded both the aorta and esophagus, and in the last two cases we were able to identify several branches which were traced back to a group of lymph nodes at the level of the pulmonary hilum. It is interesting to note that in some of these cadavers the injected dye filled certain branches and stained several lymph nodes.

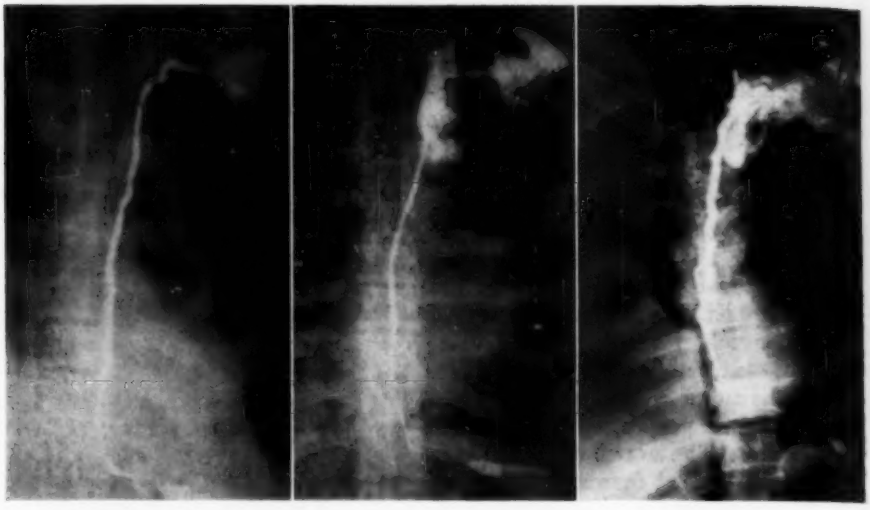

Fig. 2. Contrast filling of the thoracic duct in three cases, showing no branches and terminating in the left subclavian vein.

In the next three cadavers examined a 125 per cent solution of potassium iodide was injected into the thoracic duct at the level of the diaphragm, with the purpose of rendering it radio-opaque. The contrast medium, however, escaped through the venous channels while the cadaver was being taken from the autopsy room to the roentgen department, rendering the examination abortive. Thereafter, the left subclavian, left internal jugular and left innominate veins were tied and a left thoracotomy, after removal of the eighth rib, was carried out. The thoracic duct was dissected for 10 cms just above the aortic hiatus of the diaphragm and a needle connected to a catheter introduced into the duct. The opening into the thoracic cavity was then sutured and the body taken to the roentgen department where the contrast substance was injected under fluoroscopic observation and films obtained. With this technique, we studied twenty-six cadavers.

The radiologic examination of the thoracic duct in the antero-posterior position has, in most cases, shown a single trunk, without branches, situated either in front or to the left side of the vertebral bodies; it rises in an arch a few centimeters above the left subclavian vein, and ends in the left internal jugular vein (one case), left subclavian vein (twenty-four cases) or both (one case). (Fig. 2.) The left lateral view shows the duct situated in front of the vertebral bodies, and ascending through the posterior mediastinum up to the root of the neck (Fig. 3).

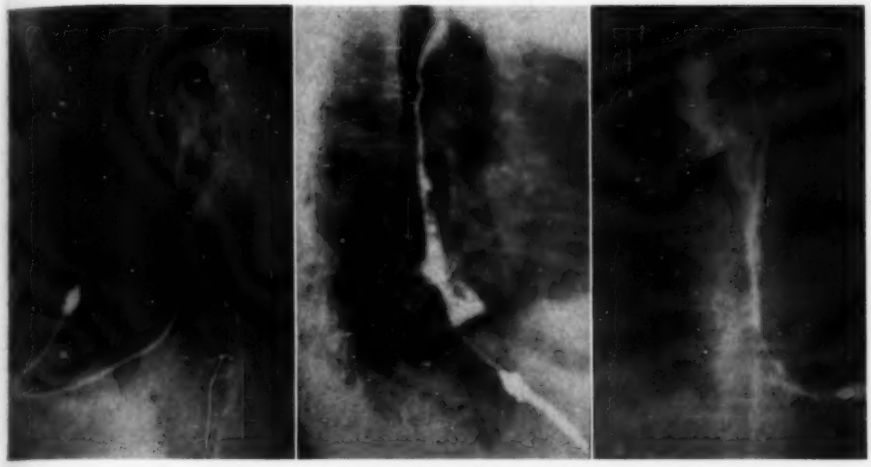

Fig. 3. Fig. 4. Fig. 5.

Fig. 3. Contrast filled thoracic duct: no branches (left lateral view).

Fig. 4. Filled thoracic duct with periaortic plexus (left lateral view).

Fig. 5. Thoracic duct dividing at its upper part into two branches; the left ending in the usual manner, the right opening into the right subclavian vein.

It is important to note that with this method we have been unable to find communicating branches between the thoracic duct and the pulmonary tissue or the lymph glands at the pulmonary hilum; this fact can only be explained in two ways: the thoracic duct does not receive the draining trunks from the lungs nor the draining trunks from the lymph glands at the hilum, or they do exist but possess valves which prevent the passage of opaque media injected in a direction opposite to that of the lymph flow.

Besides the normal radiologic appearances described, the following deviations were obtained:

1. One or several plexuses of lymphatics were outlined by the contrast medium (three cases) (Fig. 4).
2. The thoracic duct divided at its upper part into two branches to the right and left; the left ended in the usual manner, while the right opened into the right subclavian vein (one case) (Fig. 5).
3. The thoracic duct was represented by two arches in the neck, the upper ending in the left internal jugular vein and the lower in the left subclavian vein (one case) (Fig. 6).
4. The arch of the azygos vein was outlined (one case), from which

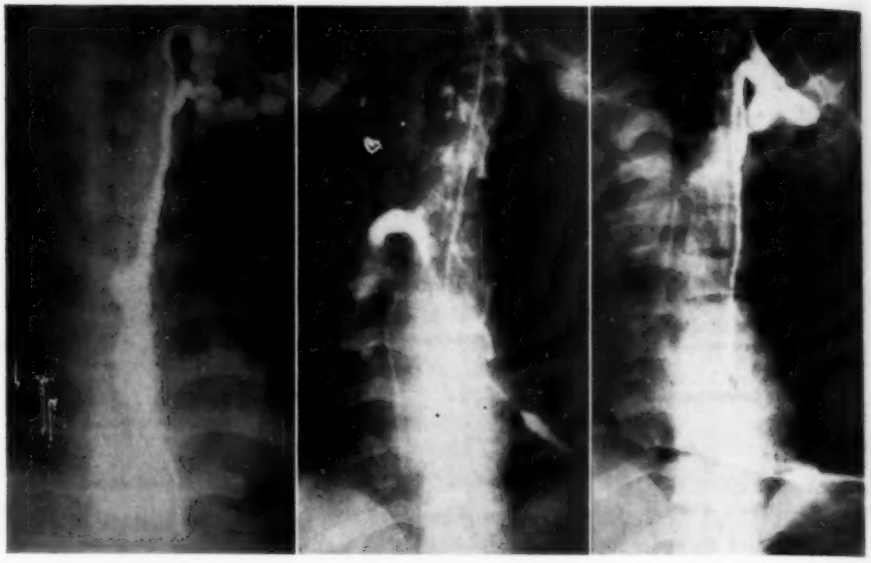

Fig. 6. Fig. 7. Fig. 8.

Fig. 6. Thoracic duct, dilated in its inferior and mid portions, with two arches; the upper ending in the left internal jugular vein, the lower in the left subclavian vein.

Fig. 7. Filled thoracic duct and arch of the azygos vein. A number of communicating branches and several lymph nodes rendered opaque.

Fig. 8. Thoracic duct divided into two vessels, which soon reunite to form a single trunk terminating in the usual manner.

we concluded that there was a connecting branch with the thoracic duct, even though it was not seen in the roentgenogram (Fig. 7).

5. The thoracic duct divided into two vessels which soon reunited to form a common stem terminating in the usual manner. (Fig. 8.)

6. In several cases a peri-aortic and peri-esophagic plexus were outlined (Fig. 4). These were also found by dissecting the thoracic duct, as mentioned previously; we did not find any mention of these plexuses in the revised literature.

7. We wish to draw attention to the fact that in several of the films a well delineated rounded shadow lies just above the pulmonary hilum; this we consider to be a lymph node rendered opaque by the contrast medium injected into the thoracic duct and thus in communication with the latter (Figs. 7 and 9). In several other films we found a number of lymph glands outlined in the thoracic cavity, neck and axilla. This may

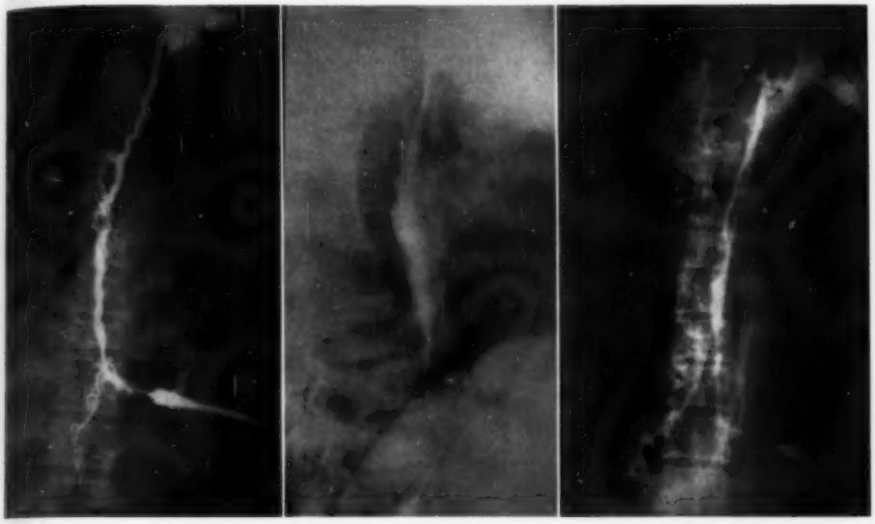

Fig. 9. Fig. 10. Fig. 11.

Fig. 9. Thoracic duct giving off a branch communicating with a lymph node at about the mid portion of the thoracic cavity; an opaque subdiaphragmatic branch also noted.

Fig. 10. Thoracic duct dilated in its vertical axis.

Fig. 11. Filled thoracic duct with a branch communicating with the hepatic veins. Several opaque plexuses of lymphatic capillaries also noted.

prove to be a most important fact, in as much as it shows that if a method (clinically feasible) to render the lymphatic system radio-opaque could be obtained, a roentgenologic study of the lymph glands would be a most important aid in the diagnosis of certain diseases of the lymphatic system.

8. In some cases we found the thoracic duct to be dilated in its vertical axis in the lower part of the thorax. (Fig. 10.)

9. In one case we noted a branch to the right lower part of the thorax communicating with the hepatic veins. (Fig. 11.)

We have also attempted to inject the contrast medium from above downwards into the thoracic duct just before its termination in the neck and at points on its intrathoracic course. Only, however, when the injection has been made just above the diaphragm have we succeeded in obtaining films of the cisterna chyli (two cases); above this point there are valves which prevent the passage of the contrast medium.

We wish to emphasize that this is only a preliminary report. We have only described the material and methods employed and the results obtained without pretending to discuss them or drawing any conclusions.

SUMMARY

The results of an investigation carried out on fifty human cadavers are described, the object being the determination of the precise anatomy of the pulmonary lymphatics by means of dissection and the injection of contrast medium into the thoracic duct. The direction of the lymph is described and discussed. In several cases, lymph glands in the thorax, neck and axilla were rendered radio-opaque. The importance of the procedure as a diagnostic clinical measure if means were found to employ it, are pointed out. The authors stress that the communication is in the nature of a preliminary report based only upon the material and methods employed.

ZUSAMMENFASSUNG

Das Resultat einer an 50 Leichen vorgenommenen Untersuchung zur Feststellung der genauen Anatomie der Lungenlymphgefässe mittels Dissektion und Kontrastinjektion in den Ductus thoracicus wird vorgelegt. Die Verlaufsrichtung der Lymphbahnen wird beschrieben und diskutiert. In einigen Fällen sind Lymphdrüsen im Thorax, am Halse und in der Axille radioopak dargestellt worden. Die Bedeutung dieser Technik für diagnostisch klinische Zwecke wird hervorgehoben, falls es möglich sein wird, sie anzuwenden. Die Verf. betonen, dass diese Mitteilung ein vorläufiger Bericht ist, der sich allein auf das beschriebene Material und die benutzten Methoden gründet.

RÉSUMÉ

Les auteurs présentent les résultats de recherches effectuées sur 50 cadavres en vue de déterminer de façon précise par dissection et injection de produit de contraste dans le canal thoracique l'anatomie des lymphatiques pulmonaires. Ils décrivent et discutent la direction prise par la lymphe. Dans plusieurs cas des ganglions lymphatiques thoraciques, cervicaux et axillaires furent opacifiés. Les auteurs font ressortir l'importance qu'aurait cette technique comme moyen de diagnostic clinique si elle devenait praticable. Ils font remarquer que cette communication n'est qu'une note préliminaire fondée uniquement sur le matériel et la méthode employés.

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FROM ROENTGEN DEPARTMENT III (DIRECTOR: INGMAR WICKBOM) AND DEPARTMENT OF HAND SURGERY (DIRECTOR: E. MOBERG), SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

ROENTGEN EXAMINATION OF BENNETT'S FRACTURE

by

Lars Billing and *K.-O. Gedda*

The fracture described in 1882 by the Irish surgeon E. H. BENNETT, and since known as 'Bennett's fracture', is an intra-articular solution of continuity of the base of the metacarpal bone of the thumb. The lower volar extremity with a greater or smaller part of the joint surface forms a fragment which is held in its correct position in relation to the greater multangular (trapezium) by its ligamentous attachment (fig. 1); at the same time, the shaft of the metacarpal bone is displaced more or less dorso-radially by the pull exerted by the musculus abductor pollicis longus (fig. 1).

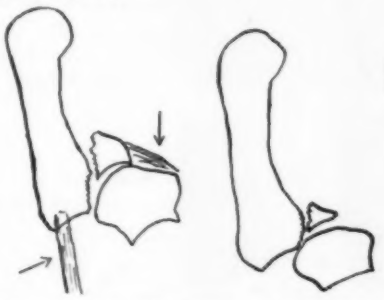

Fig. 1. Schematic drawing of a Bennett's fracture: ↓ ligament → musculus abductor pollicis longus.

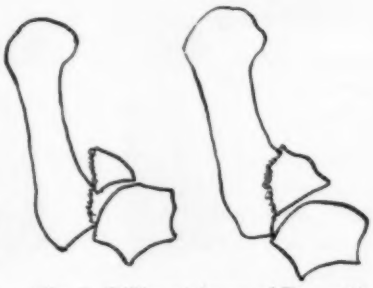

Fig. 2. Different types of Bennett's fracture. Schematic drawing of lateral views.

A Bennett's fracture which heals with deformity may, according to Swedish regulations governing workmen's compensation, constitute a 25 % disability, in other words of the same order as a fracture of the

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a. b. c.

Fig. 3. Lateral view of a Bennett's fracture. a) before operation, b) after operation, c) healed.

femur in poor position. Accurate reduction and fixation can as a rule only be achieved by operation. In the Department of Hand Surgery of Sahlgrenska Sjukhuset about 25 cases of Bennett's fracture have been operated on by a method described by E. MOBERG. Briefly this consists of opening the joint from the volar aspect and inserting a Kirschner wire

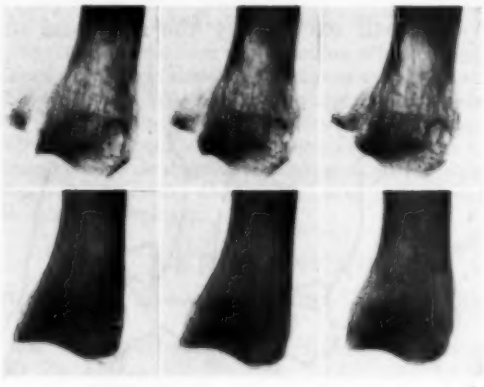


Fig. 4 a—c.

Fig. 5 a—c.

Fig. 4. Film of a preparation of M 1, in which a volar fragment has been cut and fixed with the degree of displacement as in a Bennett's fracture. a) true lateral, b) the preparation rotated 10° around its long axis corresponding to 10 degrees of pronation, c) rotated 20°.
Only in a) may the fracture and displacement be satisfactorily judged.

Fig. 5. Film of a preparation of a sound first metacarpal. a) true lateral view, b) the preparation rotated 10° as in fig. 4 b) c) rotated 30°
No characteristic difference is seen between a), b) and c).

into the small fragment. After the displacement has been corrected the wire is looped through the main body of the bone itself (fig. 3) and when healing has occurred, removed.

To show the base of the first metacarpal and the joint between it and the greater multangular correctly, a true lateral view is most important. We have not been able to find any details in the literature of what constitutes the criterium of a true lateral view. Most films published as lateral views are in fact not true laterals. The importance of the position for the correct interpretation of a Bennett's fracture is demonstrated in fig. 4.

We have attempted to find prominences in the first metacarpal bone which could be used as landmarks to determine whether the view was true lateral or not. The surface of the bone unfortunately does not show characteristic features (fig. 5). There is, however, a tubercle of constant shape situated on the dorso-radial aspect of the greater multangular (fig. 6). If the thumb be fully adducted no rotation can occur in the joint between the first metacarpal and the greater multangular. Consequently the tubercle of the latter may be used as an indication of the position of the first metacarpal bone. Furthermore, a slight prominence of the contour on the dorso-ulnar aspect of the bone, in some cases forming a small tubercle, is also present. When these two tubercles are superimposed or the dorso-radial tubercle projects not more than 1—2 mm beyond the dorso-ulnar tubercle, we have found that the view is a true lateral one.

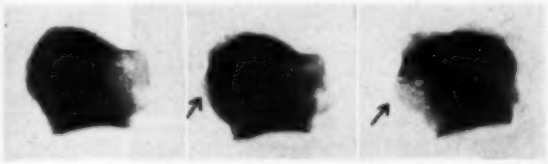
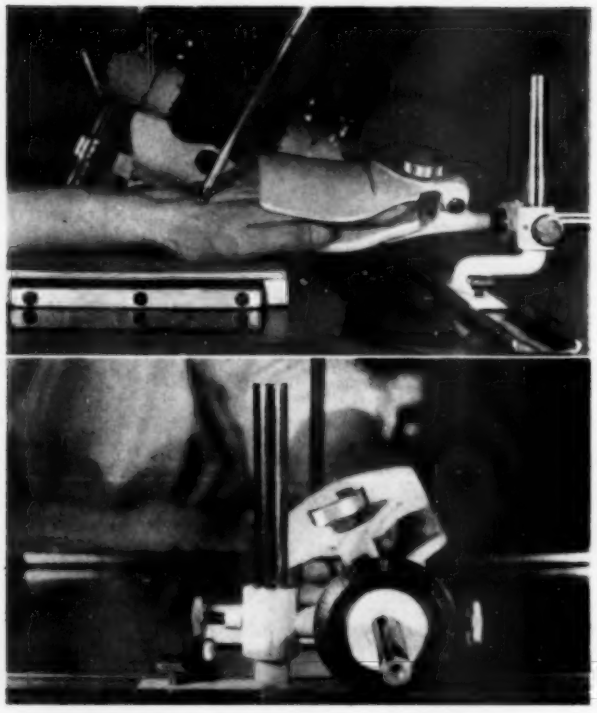


Fig. 6. Film of a preparation of the greater multangular. a) true lateral, b) the preparation rotated 10° as the metacarpal in fig. 4 b and 5 b. c) rotated 30°. The difference in rotation between a), b) and c) is obvious. The characteristic tubercle of the dorso-radial margin protrudes more if the preparation be rotated.

Fig. 7. True lateral view of a sound thumb.

Such a projection may be obtained in the vertical plane if the palmar surface of the hand be placed flat on the film and the hand and wrist



a.

b.

Fig. 8 a) and b) Apparatus for fixing the hand.

then be pronated 15°—35°; if the rotation be insufficient the dorso-radial tubercle will protrude.

With the roentgen tube displaced distally and the central ray directed at an angle of 20—30° from the vertical, the ulnar and radial joint margins of the greater multangular are accurately superimposed.

In a true lateral view the first carpo-metacarpal joint is projected over the base of the second metacarpal bone and the greater and lesser multangular bones are superimposed (fig. 7). An a—p view is easier to obtain and has been described by ROBERT (1936) among others. The hand is fully pronated, so that the dorsal aspect of the thumb lies against and in the same plane as the film. The tube is moved distally and directed at an angle of 10°—15° with the vertical. This projection gives information regarding the radial displacement of the metacarpal bone; yet such displacement is seldom observed and this view therefore affords little essential information for the treatment of Bennett's fracture.

Fig. 9 a—b.

Fig. 10 a—b.

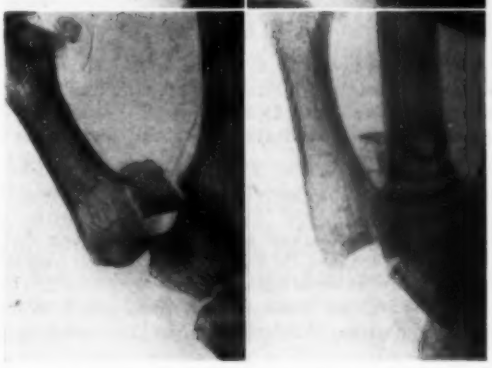


Fig. 9. Old Bennett's fracture. a) what is commonly called a 'lateral view' — the hand not sufficiently pronated, b) true lateral view.

Fig. 10. Recent Bennett's fracture. a) what is commonly called a 'lateral view' — the hand not sufficiently pronated, b) true lateral view.

In order to obtain a true lateral view, the authors have used a simple apparatus for the fixation of the hand in variable degrees of pronation and which may be read off on a protractor. The apparatus shown in fig. 8 is intended to be used in combination with the Lysholm skull table. The angulation of 20°—30° of the roentgen tube may be obtained precisely and readily. In order to standardize the technique so that a desired projection may be reproduced, the hand must be placed longitudinally in line with the revolving axis of the apparatus. The device will not hold the bases of the 2nd to the 5th metacarpal bones absolutely firmly and

some rotation of the metacarpus is possible. If the patient actively pronates or supinates the hand, a rotation of 5° of the basal part of the metacarpal region may occur; thus the hand should be relaxed.

The examination may suitably commence with a film taken with 30° of pronation and with the tube angled 25° distally. If this view be not a true lateral it is possible to judge from it how the projection should be corrected. This is often necessary since the anatomy of the hand shows individual variations.

Without the use of this apparatus it is hardly possible to perform such a correction and the apparatus is essential for repeating the examination with the same projection on a future occasion. Our experience is based on the examination of both hands of more than one hundred patients.

The importance of true lateral views is apparent in figs. 9 and 10.

The apparatus for the precise examination of fractures of the carpal bones is obtainable from AB Georg Schönander, Gröndal, Stockholm.

SUMMARY

The authors point out the necessity of a true lateral view of the carpo-metacarpal joint of the thumb for examining and treating a Bennett's fracture. Certain details of the greater multangular enable the position to be attained. A simple apparatus for the fixation of the hand is described; this facilitates positioning and makes it possible to carry out accurate repeat examinations.

ZUSAMMENFASSUNG

Die Verf. betonen die Notwendigkeit einer genau seitlichen Aufnahme des Karpometakarpalgelenkes des Daumens, um die Bennettsche Fraktur beurteilen und behandeln zu können. Das Kriterium für ein derartiges Bild ist ein charakteristisches Detail am Os multangulum majus. Die Verf. beschreiben einen einfachen Fixationsapparat, welcher die Einstellung erleichtert und die Wiederholung der Aufnahme in gleicher Projektion ermöglicht.

RÉSUMÉ

Les auteurs soulignent la nécessité de radiographies rigoureusement de profil de l'articulation carpo-métacarpienne du pouce pour le diagnostic et le traitement des fractures de Bennett. Le critère d'une bonne radiographie est un détail caractéristique du trapèze. Les auteurs décrivent un appareil simple pour fixer la main, qui facilite la mise en place et permet de répéter les examens avec la même projection.

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FROM THE ROENTGEN DEPARTMENT (DIRECTOR — AT TIME OF THE INVESTIGATION: PROF. Å. ÅKERLUND), KAROLINSKA SJUKHUSET, STOCKHOLM, SWEDEN

ASPECTS OF THE INTERPRETATION OF CONTRAST AND DETAIL IN RADIOGRAPHS

by

Ove Mattsson

Satisfactory lighting is essential for the study and evaluation of radiographs. There are, however, widely diverging opinions as to how this may be achieved. Before laying down any basic principles, it may be profitable to consider the photographic, optical and physiologic factors involved.

During the 1930s much attention was paid to the viewing of radiographs, and the associated problems were often discussed in the literature (SPIEGLER, JURIS, CHANTRAINE, STÖFFEL, HASCHÉ and others). These questions have not, for various reasons, been much debated since the beginning of the last war; recently however, certain circumstances have brought them into prominence once again. The progress made in soft tissue radiography and angiography during the last few years has resulted in an increasing number of radiographs with heavily exposed parts, presenting certain difficulties when viewed with the naked eye. Furthermore, the use of fluorescent tubes has to some extent changed previous lighting standards. The influence of illumination on the photographic density as observed by the human eye was discussed by BERGERHOFF (1948), who made an interesting summary of previous progress. BRONKHORST, TEN DOESSCHATE and FISCHER (1948) have dealt exhaustively with the relevant physiologic optics.

Photographic Factors

The ranges of film density of greatest *photographic* value are those within which the rendering of contrast is best, *i. e.* on the steepest part

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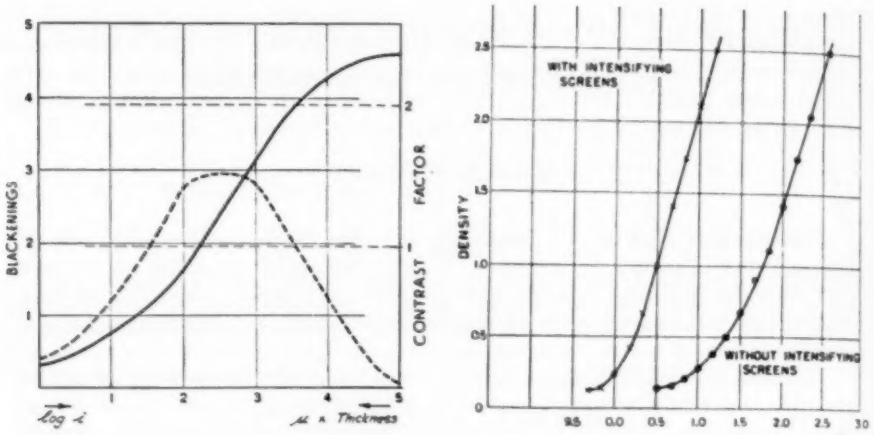
of the characteristic density (sensitometric) curve. With double-coated roentgen films, this region is situated between densities around 1 and up to, or over, 2.5, depending upon manufacture. The upper and lower limits are determined by the S-shape outline of the graph, and hence by reduced capacity of rendering differences in exposure. The upper limit is never of any great consequence, as it covers densities which can only be utilized with difficulty. The full line of Fig. 1 a is a charac-



a. b.

Fig. 1 a. Characteristic curve of a photographic emulsion (full line); the slope at each point of the curve represented by broken line (contrast factor). From G. SPIEGLER: The Radiograph from the Physicist's view-point. — 1 b. Sensitometric curves of a roentgen film made with (left) and without (right) intensifying screens. From J. F. RODERIC: Sensitometry in Roentgenology.

teristic density curve of a photographic emulsion; the broken line represents the slope at each point of the density curve — the contrast factor. Fig. 1 b gives typical sensitometric test curves for radiographs produced with and without intensifying screens. According to CHANTRAINE (1933), the density range lying between 0.6 and 2.6 appears to present an optimum for the rendering of contrast and for viewing. EGGERT (1951) places the limits at 0.3 and 2.0—2.5, the latter representing favourable viewing conditions. The more important details of soft tissue radiographs and angiographic films, the importance of which has recently increased, often lie on a high density level — usually about and above the upper values mentioned. These circumstances make the study, as well as the printing, of radiographs more complicated, especially as the

rendering of detail and contrast must be at an optimum in relatively dense regions. The author has already described methods of printing which involve contrast levelling and which permit of a more faithful rendering in a paper print of detail in dense zones adjacent to relatively translucent regions (1951).

Physiologic and Optical Factors

The ability of the *eye* to evaluate directly the range of densities above a certain value is primarily a function of the amounts of light transmitted by the emulsion. If an emulsion of density (D) = 3, is to be traversed by a fixed amount of light, a tenfold (!) increase of the amount behind the film will be necessary as compared with the amount necessary when D = 2. However, under ordinary viewing conditions the so-called simultaneous contrast will reduce considerably the definition within the dense areas if more or completely translucent parts of the film, or the transparent film margins are adjacent (SPIEGLER 1937). These circumstances have also limited the use of soft radiation technique (CHANTRAINE and PROFITLICH, 1933). Intensification of lighting, as pointed out by BERGERHOFF (1948) not only implies an increase of the simultaneous contrast, but produces dazzle which still further reduces the efficiency of the eye.

The typical reduction of visual efficiency as far as higher densities are concerned is demonstrated in Fig. 2 (after SPIEGLER and JURIS, 1936). The rendering of objects of varying radiographic opacity — "stepped" phantoms (t and T) — is represented by different degrees of photographic density (t^I and T^I) and by levels of density as observed by the eye. Although the lower densities coincide, the higher are not discernible to the eye under normal conditions — a thin curved broken line without steps (T^{II} in Fig. 2 b) represents the visual efficiency. A dashed line (T^{III}) indicates how the requirements of the eye may be fulfilled more adequately if very marked contrasts be excluded from the field of view and the simultaneous contrast phenomenon thus diminished. All steps then become visible. Selective lighting, possibly intensified for the denser parts of the film, will naturally also produce better visibility. This was the principle used in the viewer described by SPIEGLER (1934) in which a movable illuminated surface permitted a local increase of the lighting where necessary. In this case, compensation doubtlessly produced the favourable condition indicated by HASCHÉ (1933), namely that the field of vision of the eye should cover an area of less irregular lighting; it was suggested that this increased the contrast sensitivity of the eye. But later, after continued experiments (1936), SPIEGLER and JURIS maintained that the ability of discerning detail was a matter of its surroundings.

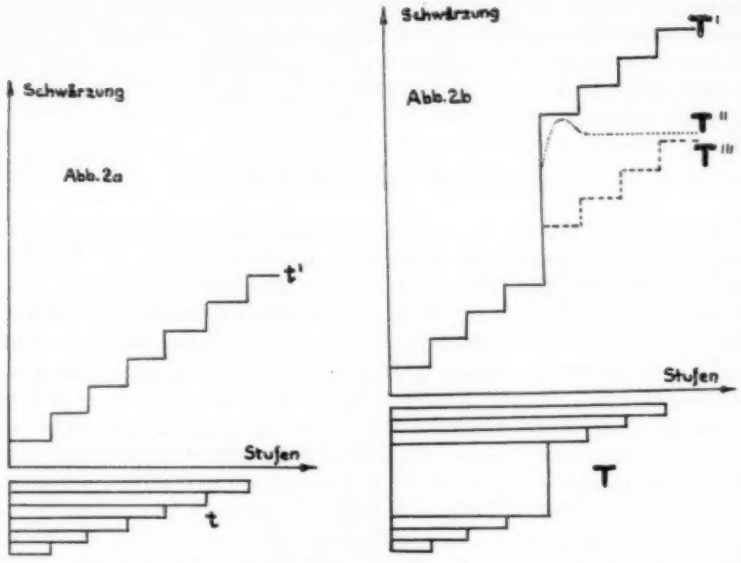


Fig. 2 a and b. The rendering of objects of varying radiographic density — "stepped" phantoms (t and T). The levels of density observed correspond to the different degrees of lower *photographic* density (t^I and T^I). The typical reduction of visual efficiency with higher densities is demonstrated in Fig. 2 b, the broken line T^{II} corresponding to the visual capacity of the eye. If very large contrasts are excluded from the field all steps will be visible — (dashed line T^{III}). From G. SPIEGLER and K. JURIS: Grosse Kontraste und Sichtgüte.

The smaller the area of the film examined, the more the simultaneous contrast diminished. Thus an increased amount of detail will be discernible in denser areas after shading off the neighbouring and more translucent regions. According to experiments made by SCHUMACHER (1941) the most favourable condition seemed to be reached when a radiograph was surrounded by a region of $^1/_{10}$ of its own luminosity. This referred to conditions comparable to those existing when an ordinary chest film was examined at a distance of 0.4 m. When examining dense parts of the film for detail, *total* shading of the surrounding parts of the visual field seemed to give ideal conditions. In 1937 SPIEGLER used a blackened gray scale to demonstrate the importance of masking off *all* light from surrounding regions. He reported, inter alia, that if the eye were able to discern in a film details up to a density of D = 2.3 when the level of illumination was 400 lux (one lux = 1 lumen per square metre), then the same degree of visibility might be produced by efficient masking with no more than 40

lux, or $^1/_{10}$ of the first value. On the other hand, more intense lighting combined with masking produced a gain in visibility in the dense regions, so that the eye might discern detail up to no less a degree of density than D = 3.4. SPIEGLER also referred to devices employed by HOLZKNECHT and STÖFFEL. The former used a cardboard tube for the study of denser parts of the film. STÖFFEL (1930) designed a telescope-like instrument: a tube containing lenses for the study of film detail. These contributions however, have not been generally accepted or their advantages sufficiently calculated. The best way, from every point of view, of obtaining increased evaluation of detail in the denser areas seems to be the *masking off* of unimportant surrounding regions. Although this principle is fully proved, it has not apparently been put into universal practice.

Among the factors which contribute materially to the insufficiency of the human eye in studying density detail, certain purely physical facts deserve to be mentioned. One of these is the scattering of light inside the eye. A proportion of the incident light will be irregularly reflected in the ocular media and reflections at the principal surfaces will also produce disturbing effects. In addition, considerable dispersion will take place by reason of the colloidal structure of the media. The amount of light which is reflected and dispersed has been determined by RAEDER (1922) and RAYLEIGH, respectively. We know from everyday life that these factors are important. The ability of the eye to discern details in a dark street at night is greatly enhanced if the eye be shaded from the direct light of a nearby street lamp. The same thing is very easy to observe when driving a car, although the question of dazzle then commonly arises.

Effect of Light Reflection from the Film Surface

A very important cause of the difficulty of the eye to discern detail in dense regions is the reflection of light from the film surface. The denser regions of a radiograph, when examined through a magnifying glass, have an irregular appearance; the irregularities correspond to silver grains situated immediately below the surface. Areas of lower density, on the contrary, appear to be more smooth. If the light be directed from a source situated some distance away, different densities will show varying degrees of reflection, permitting the individual study of each of the two emulsions (MATTSSON, 1950). In diffuse light, however, the difference between single densities is less marked, and they both reflect a considerable amount of light. Under the viewing conditions which usually prevail, this reflected light is a disturbing factor, the full importance of which appears to have

been previously neglected.[1] The difference between the amounts of light transmitted by various regions of the emulsion, ranging in density from 1 to 2, is most marked for the lower densities. Between densities 1 and 2 there is a difference in transparency of $^1/_{10}$ and $^1/_{100}$ or $^9/_{100}$. The corresponding differences between densities 2 and 3 is $^1/_{100}$ and $^1/_{1000}$, or $^9/_{1000}$; in other words, it is 10 times smaller.[2] The visualization of detail is wholly dependent on whether the small amounts of light transmitted are correctly interpreted by the eye. If, due to reflection on the film surface as well as to scattering of light inside the eye, a disturbing diffuse illumination is superimposed on these low values of lighting, detail will be immensely reduced, in fact just as much as the relative difference in the quantity of light in various regions is reduced by the addition of homogeneous scattered light. Even at a low level of lighting this additional illumination raises the light impressions from all parts of the image to the same extent; and the relationship between the small amounts of light from different regions of varying density will then be reduced most. The phenomenon may be expressed thus: the eye is no longer capable of discerning differences between the dense areas when, due to pseudo-illumination, the amounts of light reaching the eye show only small variations.

It is difficult to avoid reflection produced by light coming from the viewer's side. This arises indirectly from the viewing cabinets, from lighted objects — such as the body of the operator himself (often dressed in white) and from other sources of illumination. To a certain extent, however, the reflection may be reduced by avoiding unnecessary brightness in the viewing room; daylight should be excluded. The viewing lanterns should be in use only one at a time — a precaution which, when fluorescent tubes best suited for continuous operation are employed, is uneconomical.

A similar problem was discussed by GOLDMARK (1950) in connection with television sets in well-lighted rooms. The television screens reflect the room light and a lower limit is set to the darkest shade reproducible. The effect will be reduced by the use of a so-called "neutral density filter" which reduces the reflected ambient light of the fluorescent pigment to a higher extent than the television image itself.

The author has carried out experiments with a photometer to evaluate the importance of reflected light. Test films of varying densities were placed in position together with ordinary films in the viewing cabinets which were illuminated by fluorescent tubes. The tests were made under

[1] Attempts to eliminate the effects of surface reflection by means of polarization are doomed to failure; diffuse light shows no uniform polarization.

[2] Transparency represents the fraction of the light transmitted by the film, opacity is its inverted value and density is the decimal logarithm of the opacity (MATTSSON, 1951).

various conditions corresponding to those normally existing when examining radiographs. The reflected light compared with the amount of light transmitted by the film was measured. In a case where the film density was only 0.85 the reflected light amounted to $^1/_{20}$, though the viewing cabinet was the only source of light in the room and the reflection emanated from objects in the room illuminated by it; three or four times as much reflected light could be registered for the same density if there were other sources of light in the room. These figures give some idea of the importance of reflected light, and naturally will be much more pronounced with higher densities and with lower transmissions. The tests demonstrated these facts clearly.

The tests were performed in the following manner: A small photocell fitted with a special tubular shade giving a limited measuring field corresponding to a viewing angle of 30°, was used. It was mounted on a stand and placed at a distance from the test films where the influence of any reflection from the instrument was practically eliminated (more than 8 inches). The values were read on a separate galvanometer. The measurements were made with the instrument placed vertically perpendicularly against the film surface at chest height.

The test films were ordinary radiographs and films with various degrees of homogeneous blackening; the latter gave more adequate reflections for the respective densities. A few figures will be quoted.

Firstly, all reflections were excluded as far as possible by a black cardboard shading arrangement and a basic value was determined. Readings were then taken with the surface reflections included under varied conditions. For one test film with a density of 0.85 the surface reflection amounted to 5 % as long as there were no other sources of light in the room; the reflection then emanated from objects (wall, etc.) illuminated by the viewing cabinet itself; if an observer dressed in white stood in front of the lantern (and behind the instrument) in a position for viewing, the reflection value rose to 7 %. If two adjacent cabinets were lighted (with no observer present) the value rose to about 17 % above the basic value. The presence of an observer produced a somewhat lower value (about 14 %) — the screening partly prevented the other sources of light from producing reflection.

Readings taken for greater densities gave considerably higher values. The absolute reflection values seemed to be the same; but with small quantities of transmitted light they predominated.

In addition to the considerable magnitude of reflection under working conditions the tests show its importance when there are no sources of light other than the viewing lantern in the room.

All these facts provide ample evidence of the value of correct lighting and viewing conditions.

The Value of Intense Illumination

The general opinion is that a strong small source of light should be used for the best evaluation of the denser film detail. This conception, the erroneousness of which has been pointed out by SPIEGLER (1937), and BERGERHOFF (1948) is nevertheless still maintained in many quarters

and numerous "high-power" lamps of relatively intense illuminating power regularly appear on the market, a recent example being of the mercury arc type. The main idea is, that if the same transmitted quantity of light be required in parts of a film possessing a density = 3 as in parts with a density = 2, the lighting must be 10 times more intense. Thus, a 250 watt lamp must be substituted for one of 25 watts. As a rule it will not be possible to use higher outputs by reason of the considerable heat generated. The amount of light produced and transmitted by the film is of course increased although the detail may not obviously be improved to the same extent. The latter factor depends on the light which reaches the film surface from the observer's side and produces reflection. This light, in turn, emanates mainly from the original source of illumination (see above), and it is not unreasonable to suspect that it also increases directly with the intensity. Any gain obtained must obviously be of a small order.

In reality the circumstances are not quite so bad although it must be stressed that as long as reflected light is present in front, there is but little profit in increasing the illumination from behind; to this is added the risk of dazzle at the higher levels, which again reduces the value of the intensity still more.

A Simple Device for Accurate Interpretation of Radiographs

One main principle, at any rate, is to establish suitable working conditions for the eyes by masking off the insignificant part of the field of vision, in the way indicated above. The other is to prevent reflection from the film surfaces. By this way the ideal conditions seem to be almost achieved. A slight increase in the illumination may of course be valuable, but it is never possible to make any great gain in this way. The need for highpower lamps is eliminated, and the eyes are spared.

The author has designed a cheap and simple viewer (AB Georg Schönander, Stockholm) which permits the study of heavily exposed radiographs under optimal conditions. Fig. 3 shows its shape and construction, and Fig. 4 depicts it in use. The viewer consists of a hood made of cardboard in the shape of a truncated pyramid, one end of which is shaped in such a way as to form a light-proof seal around the eyes; the opposite end has a square opening and rests against the image. A transverse division with two holes corresponding to each eye, is fixed in the middle; this division reduces the effect of reflection from the walls and also increases the rigidity of the construction. The length of the viewer corresponds to a comfortable viewing distance for normal refraction or ordinary spectacle correction. The inside is finished in matt black to eliminate reflection.

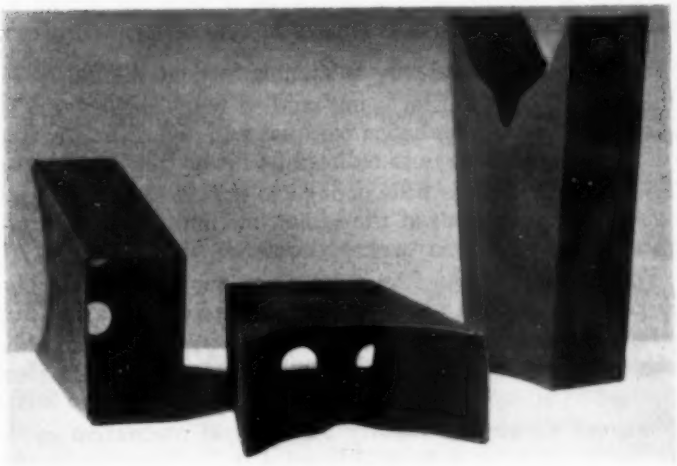


Fig. 3. The special viewer, showing its simple construction.

Fig. 4. The viewer held close to the radiograph to eliminate reflection.

The viewer is covered with a clothtype of material which is waterproof — this is essential when it is used in connection with wet films.

The advantages obtained may be summarized as follows:

I. Only light from the film being studied reaches the eyes. This fact reduces the effect of simultaneous contrast and the diffuse scattering of light in the media of the eye is reduced as far as possible.

II. The field of vision is wide enough to permit a survey of a film of, say, a wrist or an ankle, but at the same time limited enough to exclude large lighted areas which may create dazzle.

III. The viewing of the film from close quarters wholly eliminates reflection from the surface which tends to reduce contrast and definition.

IV. High-power sources of light are not required. The masking eliminates the lowering of room lighting: an advantage when fluorescent tubes are used. The eye is relieved of excessive changes in adaption.

V. Binocular viewing, necessary for optimal evaluation of detail, is possible.

VI. The viewer may be used to advantage by persons wearing spectacles, which are in themselves sources of annoying reflections. Compound lenses of cameras usually have coated surfaces in order to reduce reflection; this method has not been developed for spectacles so far. Optical lenses unlike photographic lenses enclosed in a camera, receive light both from the front and behind; this necessarily causes a considerable amount of reflection. The device described above is excellent when used with spectacles, and eliminates all light from sources other than the limited object to be examined. The shape of the viewer ensures that good contact with the face is obtained when spectacles are worn (Fig. 4).

Besides its daily use in a radiographic department the viewer has proved most handy for studying radiographs under unfavourable conditions of lighting — in out-patient clinics, surgical departments, etc., where suitable arrangements for studying radiographs are not always available; in addition, the disturbing effects of daylight are overcome.

The viewer has proved quite suitable for the satisfactory examination of wet films. Intense and often hot sources of light are not required. The irritating reflection from the glossy wet film surface, is avoided.

SUMMARY

The author discusses the photographic, physiologic and optical factors influencing the interpretation of detail and contrast in radiographs, especially those heavily exposed. The importance of reflection from the film surface is pointed out. A simple viewing device which eliminates reflection and produces optimal functional conditions for the eyes, is described.

ZUSAMMENFASSUNG

Der Verf. bespricht die photographischen, physiologischen und optischen Faktoren, welche die Erkennung von Einzelheiten und Kontrasten in Röntgenbildern, besonders von stark exponierten, beeinflussen. Die Bedeutung der Reflektion von der Filmoberfläche wird hervorgehoben. Der Vorteil sehr starker Lichtquellen wird gewöhnlich sehr überschätzt. Eine einfache Betrachtungsanordnung, welche die Reflektion eliminiert und für das Auge optimale funktionelle Bedingungen schafft, wird beschrieben.

RÉSUMÉ

L'auteur étudie les facteurs photographiques, physiologiques et optiques qui influent sur l'interprétation des détails et des contrastes des radiographies, en particulier de celles qui sont surexposées. Il souligne l'importance de la réflexion sur la surface du film. Il décrit un dispositif simple pour examiner les films, qui élimine la réflexion et place l'œil dans les meilleures conditions fonctionnelles.

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ACTION DES RAYONS ROENTGEN, DU CYANURE ET DE DIVERS RADIOPROTECTEURS SUR LES INFUSOIRES

par

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Le cyanure (0.1 mg NaCN) injecté avant une irradiation de 700 r. mortelle pour toutes les souris de notre élevage, permet une survie de 70 à 75 % (1, 2, 5 et 7). Diverses hypothèses pourraient expliquer ce fait:

1°) Le cyanure réduit les ponts —S—S—; il pourrait augmenter dans l'organisme la teneur en fonctions —SH dont le rôle dans la radioprotection a été souligné par de nombreux auteurs (voir bibliographie dans 3). Mais l'action du cyanure s'ajoute à celle du glutathion réduit (2); la concentration de cyanure atteinte dans l'organisme est sans aucun doute trop faible pour excercer une action réductrice, et personne n'a réussi à démontrer une diminution des fonctions thiols dans le sang ou les tissus d'un animal qui vient de recevoir une dose mortelle de rayons roentgen.

2°) Etant donné que la plus grande partie, sinon la totalité, des effets des radiations ionisantes doit être attribuée à l'action des radicaux libres qui proviennent de l'hydrolyse de l'eau (1), ne doit-on pas supposer que le cyanure inhibe l'action surtout oxydante de ces radicaux libres? Cette idée est d'autant plus vraisemblable que le cyanure est inefficace quand on l'injecte immédiatement après l'irradiation, c'est à dire qu'il doit être présent au moment où ces radicaux libres sont actifs; mais aucun physicochimiste n'a encore tenté l'expérience.

P. ALEXANDER (communication personnelle) a montré que le cyanure inhibe partiellement la dépolymérisation, par les rayons roentgen, d'un polyméthacrylate en présence d'oxygène.

3°) Le complexe formé par le cyanure et les enzymes qu'il inhibe pourrait être radiorésistant; après l'irradiation, le complexe se dissocie parce

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que la concentration en CN^- baisse très rapidement dans le plasma (excrétion et détoxication en SCN^- par le foie) et l'enzyme redevient actif. Cette hypothèse est calquée sur les faits établis pour la cholinestérase. Cet enzyme est détruit par les esters phosphoriques (D.F.P., T.E.P.P., Tabun, etc. . .); mais, si au préalable on le combine à l'ésérine, il est protégé contre ces esters phosphoriques. La combinaison ésérine + cholinestérase est réversible; si on élimine l'ésérine, l'enzyme redevient actif.

Corollaires de cette hypothèse: a) Les rayons roentgen doivent inactiver les systèmes enzymatiques sensibles au cyanure. Les recherches «in vitro» de BARRON et collaborateurs (voir 1) avec des enzymes cristallisés n'ont pas fait apparaître ce fait: au contraire, *in vitro*, les enzymes qui ont besoin de groupes —SH pour fonctionner (c'est à dire les enzymes *activés* par le cyanure) sont les plus radiosensibles.

In vivo, on a signalé une inhibition de la catalase et de la cytochrome réductase, mais ces observations sont insuffisantes.

b) La résistance d'un organisme aux rayons roentgen doit accompagner la résistance au cyanure. La radiorésistance des infusoires est bien connue, et de divers côtés on a signalé leur peu de sensibilité aux cyanures (pour bibliographie, voir HUNT, 9). Nous avons donc choisi à l'intérieur d'un même genre, quatre espèces d'infusoires, nous avons comparé leur radio- et leur cyanuro-résistances, nous avons recherché si elles varient au cours du cycle évolutif de ces ciliés; enfin, nous avons aussi vérifié sur ces organismes l'action de divers radioprotecteurs.

I. Technique

1) *Matériel.* Nous avons utilisé pour nos recherches des infusoires ciliés, Hyménostomes histiophages de la famille des *Ophryoglenidae* (*O.*) parmi lesquelles nous avons choisi quatre espèces qui présentent des différences morphologiques caractéristiques: *O. atra*, *O. mucifera*, *O. pectans* et *Deltopylum rhabdoïdes*.

Les diverses phases du cycle évolutif physiologique de ces ciliés sont les suivantes:

L'infusoire chasseur, long, fusiforme, nage rapidement dans les directions les plus variées en quête d'une proie. Nous désignons cet individu sous le nom de théronte. Il se nourrit, accumule des réserves, augmente considérablement de volume et devient alors un trophonte. Le plus souvent, ce dernier a d'abord la forme d'une bourse pleine avec un rostre clair; mais il devient très vite parfaitement ovoïde; à ce stade protomonte, il s'immobilise ou s'enkyste et on l'appelle dès lors un tomonte. Le tomonte subit deux divisions successives donnant naissances à quatre tomites qui, une fois libérés, nagent rapidement et deviennent eux-mêmes des théronte chasseurs (Fig. 1).

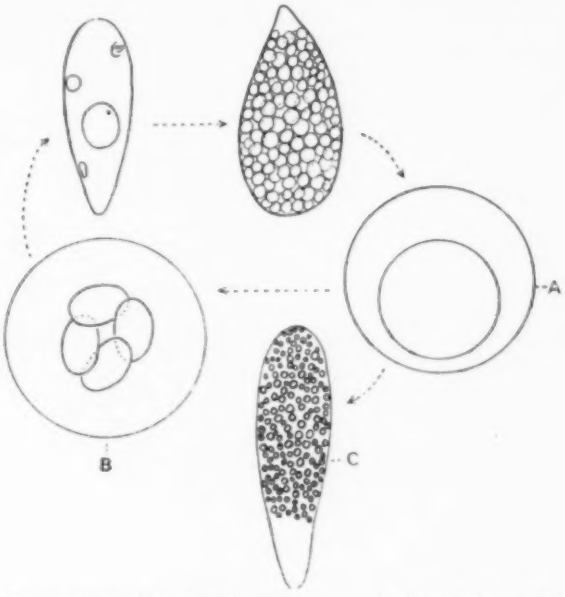

Fig. 1. Cycle d'*O. mucifera* n. sp. — A. Tomonte arrondi dans le kyste; B. Tomites légèrement écartés les uns des autres sous l'enveloppe kystique; C. Individu migrateur. Gross. × 100.

Pour les quatre espèces envisagées dans ce travail, toute la première partie du cycle est identique, mais au moment où l'Infusoire devient tomonte, on observe les variantes suivantes:

a) aucune formation de kyste: *Deltopylum rhabdoïdes*,

b) formation d'un kyste muqueux lâche, le tomonte restant allongé sous le kyste: *O. pectans*,

c) formation d'un kyste muqueux assez lâche mais sous lequel l'ophryoglène est enroulée sur elle-même: *O. mucifera*,

d) formation d'un kyste muqueux: *O. atra*.

2) *Irradiation*. — Les irradiations ont été réalisées à l'aide d'un tube Machlett A.E.G. 50, à fenêtre de béryllium, avec les données physiques suivantes: 30 Kv, 50 mA, filtre 0, H.V.L. 0.06 mm Al. Débit moyen 30,000 r/m. Distance focale 10 cm. Champs circulaire d'un diamètre de 5 cm.

Les infusoires (10 individus en moyenne) nagent dans une quantité constante d'eau (0.1 cc) placée dans une lame creuse en matière plastique baignant dans une cuve d'eau maintenue à une température constante (20°).

Les doses administrées ont été calculées d'après le tableau de JENNINGS (10) après vérification du rayonnement à l'aide d'un dosimètre universel Siemens.

3) *Cytologie et Histochimie.* — Les techniques histologiques qui suivent ont été réalisées:

1°) Réactions caractéristiques des lipides: Noir Soudan, Bleu B.Z.L., réaction plasmale de Feulgen sur frottis secs.

2°) Mise en évidence des corps hydro-carbonés tels: amidon, cellulose, pectine, glycogène: réaction d'Hotchkiss, comparée d'ailleurs à la réaction de Bauer caractérisant plus particulièrement et presque uniquement le glycogène.

3°) Etude de la structure ciliaire superficielle des Infusoires irradiés: imprégnation argentique d'après CHATTON et LWOFF (1930—1935).

4°) Examen cytologique; a) noyau par la méthode de Feulgen; b) Microsomes ribonucléiques par la coloration d'Unna-Brachet sur frottis.

II. Action des rayons roentgen

1) *Doses mortelles*

Pour chaque espèce, prise aux différentes phases du cycle physiologique, nous avons tenté de déterminer

a) *la dose maximum supportée* permettant une survie, sans tenir compte tout d'abord des modifications possibles du cycle.

b) la dose mortelle immédiate, c'est à dire la dose qui ne laisse aucun survivant 10 à 15 minutes après la fin de l'irradiation.

Nous avons consigné nos résultats dans le tableau I.

Tableau I

Doses maximum de rayons roentgen supportées et doses immédiatement mortelles (en roentgen) pour chaque phase du cycle de quatre Ophryoglenides

Espèce	*O. pectans*		*O. atra*		*O. mucifera*		*Deltopylum rhabdoides*	
Phases du cycle	Dose maximum supportée	Dose mortelle immédiate	Dose maximum	Dose mortelle	Dose maximum	Dose mortelle	Dose maximum	Dose mortelle
Thérontes affamés ...	200,000	300,000	300,000	600,000	450,000	600,000	300,000	450,000
Thérontes	300,000	600,000	450,000	900,000	600,000	1,050,000	750,000	850,000
Trophontes	600,000	750,000	1,000,000	1,050,000	1,100,000	1,200,000	750,000	900,000
Tomontes (1ère div.) ..	600,000	750,000	—	—	—	—	750,000	1,050,000
Tomontes (fin 2e div.)	600,000	750,000	—	—	—	—	810,000	1,100,000
Tomites prêts à sortir du kyste	750,000	900,000	—	—	—	—	—	—

Ce tableau permet de conclure que:

1°) *O. pectans* à toutes les phases du cycle est la plus fragile des espèces étudiées.

2°) L'individu affamé est plus sensible que le théronte normal, ce dernier étant lui-même plus réceptif que le trophonte.

3°) le tomonte est encore plus résistant que le trophonte surtout lorsqu'il est en voie de deuxième division.

4°) La résistance maximum est réalisée par le tomonte prêt à sortir du kyste.

Nous avons constaté, au cours de ce premier examen, que l'Infusoire irradié avec une dose maximum, mais non mortelle, ne survit que s'il est mis en présence de tissu nourricier aussitôt après l'irradiation.

Nous avons essayé d'expliquer ces faits, soit par les modifications morphologiques du protiste, soit par des transformations chimiques du protoplasme. A cet effet, nous avons d'abord examiné si, du point de vue de la morphologie externe, des modifications étaient apparues après irradiation, puis nous avons comparé la cytologie et l'histologie des infusoires irradiés à celles des normaux.

2) *Morphologie externe*

Le pôle antérieur du corps chez un théronte normal est généralement arrondi (Fig. 1) mais dès le début de l'irradiation, l'individu change de forme et devient très acuminé à l'avant, exactement comme au moment de l'attraction vers un tissu. Lorsque le théronte a reçu une dose mortelle, il semble contracté sur lui-même et l'extrémité antérieure très aiguë de la cellule a disparu. Cependant, la bouche existe encore mais elle semble parfois lésée. Du fait du gonflement de la vacuole contractile (fig. 2), le péristome, en forme d'entonnoir, est complètement dévaginé (fig. 3). Le trophonte comme le théronte possède une vacuole contractile dont l'excrétion est complètement bloquée et prend une telle importance que les nombreuses inclusions digestives non compressibles, sont, de ce fait, repoussées contre la membrane protoplasmique. Ceci détermine la formation de hernies en plusieurs points du corps de la cellule mais spécialement au niveau du péristome (fig. 4).

Il semble donc qu'une dose mortelle d'irradiations déclenche un bloquage de l'excrétion chez tous les Hyménostomes envisagés ici.

3) *Morphologie interne. Cytologie*

Après la réaction nucléale de Feulgen, les macronuclei et les micronuclei des infusoires qui ont reçu une dose mortelle présentent exactement le même aspect et la même intensité de coloration que ceux des individus normaux. De même, la ciliature superficielle ne semble pas altérée et l'imprégnation à l'argent nous permet de voir que les rangées de cinéto-

Fig. 2. Théronte d'*O. atra* ayant reçu une dose mortelle de rayons roentgen. A. Gonflement de la vacuole contractile qui occupe presque tout le protoplasme. B. Pôle antérieur tronqué (Imprégnation à l'argent). Microphoto. Agrandissement × 350.

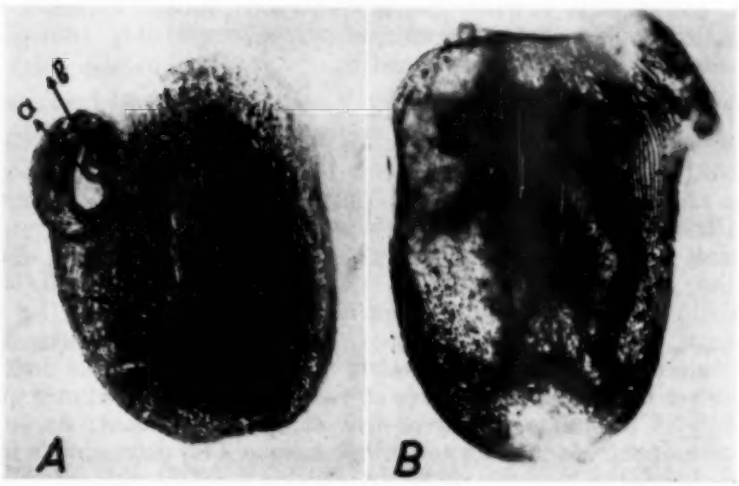

Fig. 3. Théronte d'*O. mucifera* ayant reçu une dose mortelle de rayons roentgen. Le péristome normalement invaginé est complètement ressorti. A. *face,* on aperçoit les membranes vibratiles buccales en profondeur (a) et l'organe en verre de montre (b). B. *profil;* imprégnation à l'argent. Microphoto. × 350.

somes sont absolument identiques avant ou après l'action du rayonnement chez les thérontes comme chez les trophontes. On note parfois un léger épaississement des rangées ciliaires qui est peut-être dû à la modification de la membrane protoplasmique sous l'effet du gonflement de la

vacuole contractile (fig. 5). Le théronte ayant reçu une dose maximum mais non mortelle, mis en présence d'un tissu, se nourrit aussitôt puis s'enkyste et se divise normalement. Le cycle biologique ne semble en rien modifié et les individus fils gardent apparemment l'aspect du théronte normal.

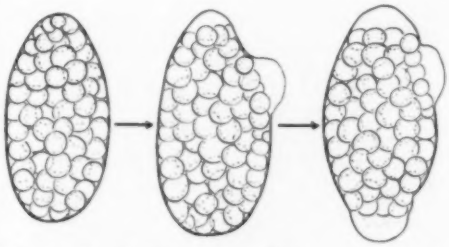

Fig. 4. Trophonte d'*O. pectans* au cours de l'irradiation présentant les hernies caractéristiques. × 100.

Il serait utile de reprendre ces expériences au point de vue génétique sur infusoires isolés, cultivés aseptiquement et suivis pendant de nombreuses générations.

4) *Histochimie protoplasmique*

Le protoplasme des Hyménostomes histiophages est riche en acide ribonucléique, en hydrate de carbone, en groupes SH et, à certains stades du cycle, en lipides.

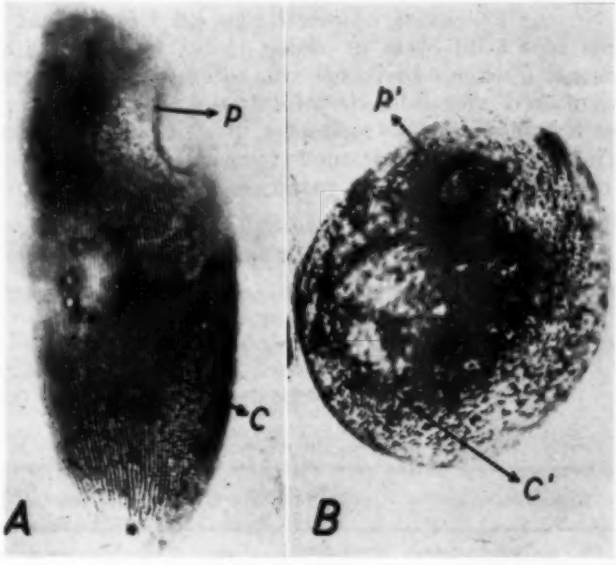

Fig. 5. A. Théronte normal. B. Théronte irradié; c et c' = cinéties; p et p' = péristomes; (imprégnation à l'argent). × 550.

Fig. 6. Théronte d'*O. pectans* très affamé et s'étant enkysté de faim; réaction d'Hotchkiss. × 400.

Fig. 7. Tomite d'*O. pectans* venant de sortir du kyste; réaction d'Hotchkiss. ×350.

1°) Acides ribonucléiques: A l'état normal, la réaction de Unna mettant en évidence les acides ribonucléiques est très fortement positive pour chaque aspect du cycle physiologique et pour toutes les espèces indifféremment. Chez les individus très affamés, il y a peut-être une légère diminution d'intensité de la coloration.

Chez les thérontes ou les trophontes irradiés, la coloration de Unna reste aussi intense. Il semblerait que le taux d'acide ribonucléique dans la cellule ne subisse pas de grandes variations pendant ou immédiatement après l'irradiation de celle-ci.

Tableau II

Abondance des hydrates de carbone chez quatre ophryoglenides. Détection par les réactions d'Hotchkiss et de Bauer

0	Réactions négatives — voisines de 0.
±	Réactions faiblement positives.
+	Réactions moyennement positives.
++	Réactions positives.
+++	Réactions fortement positives.
++++	Réactions très fortement positives.

Espèce	*O. pectans*	*O. atra*	*O. mucifera*	*Deltopylum rhabdoides*
Théronte sortant du kyste...	++	+++	++++	+++
Théronte normal.....	+	+	+++	+
Théronte enkysté de faim ...	0	±	+	±

2°) Hydrates de carbone: A l'état normal, la teneur en hydrates de carbone, c'est-à-dire, en amidon, cellulose, pectine, glycogène, mucine, est extrèmement différente d'une espèce à l'autre et pour une même espèce, on enregistre de grandes variations au cours du cycle physiologique.

Les réactions d'Hotchkiss et de Bauer nous ont permis de préciser la répartition des éléments précités dans la cellule infusorienne normale — voir tableau II.

Chez toutes les espèces, en tenant compte naturellement de leur teneur respective en hydrates de carbone, l'individu affamé donne des réactions d'Hotchkiss et de Bauer très faiblement positives (fig. 6).

Le tomite sortant du kyste contient au contraire des réserves hydrocarbonées importantes (fig. 7) et le tomite en division contient à la fois des hydrates de carbones protoplasmiques augmentés d'un apport extérieur contenu dans les inclusions digestives (fig. 8). *O. pectans* possède une faible quantité d'hydrate de carbone protoplasmique tandis qu'*O. mucifera* est beaucoup plus riche (fig. 9).

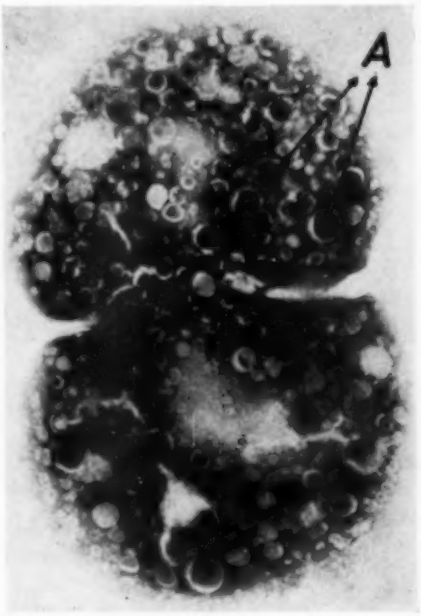

Fig. 8. Trophonte d'*O. pectans* en 1ère division. A.: inclusions digestives; réaction d'Hotchkiss. × 300.

Après une irradiation de 20 à 30', on note dans toutes les espèces une intensité moindre des réactions précitées. Ainsi, chez les ciliés témoins (théronte), les réserves glycogéniques très abondantes (fig. 7) se trouvent sous forme de vacuoles de taille variable (fig. 10); chez les individus irradiés au contraire, ces inclusions sont absentes.

3°) Lipides: Chez les individus normaux, la répartition des lipides varie, elle aussi, au cours du cycle. Les colorations au bleu B.Z.L., au noir Soudan et la réaction plasmale de Feulgen donnent les résultats que nous avons schématisés dans le tableau III.

Le seul moment où les Ophryoglenidae prennent assez fortement le noir Soudan et le bleu B.Z.L. correspond à la présence dans le protoplasme d'inclusions digestives lipidiques. Celles-ci disparaissent au cours de la

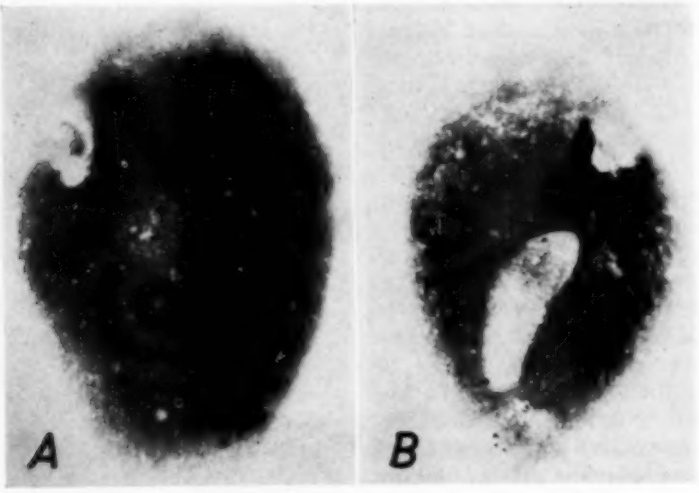

Fig. 9. A. Théronte d'*O. mucifera*, B. Théronte d'*O. pectans;* réaction d'Hotchkiss. ×350.

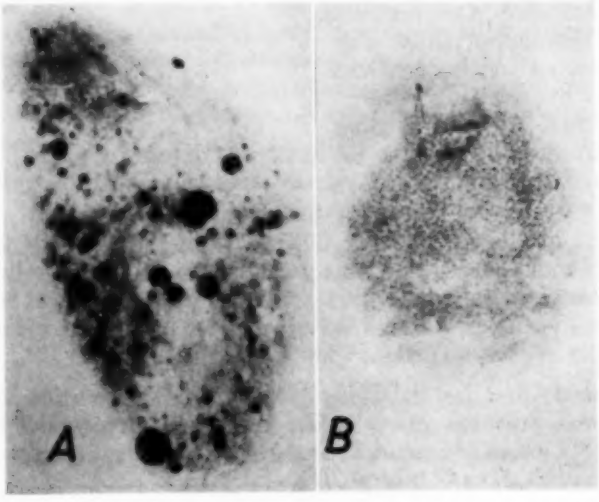

Fig. 10. Théronte d'*O. pectans:* A. normal, B. irradié; réaction de Bauer. ×550.

Tableau III

Abondance des lipides dans quatre espèces d'Ophryoglenides.

0 Réactions négatives — voisines de 0.
± Réactions très faiblement positives.
+ Réactions moyennement positives.
++ Réactions positives.

Réactions	Espèce / Phases du cycle	*O. pectans*	*O. atra*	*O. mucifera*	*Deltopylum rhabdoides*
Bleu B. Z. L. Noir Soudan	théronte	±	±	±	±
	trophonte 1e div..	++	++	++	++
	tomites de 2e div.	+	+	+	+
Réaction plasmale de Feulgen	théronte	0	0	0	0
	trophonte	+	+	+	+
	tomites de 2e div.	±	±	±	±

division et le tomite de 2e division, prêt à sortir du kyste, contient aussi peu de réserves lipidiques que le théronte normal.

Après irradiation, nous n'avons vu apparaître aucune modification dans la teneur en lipides du protoplasme des hyménostomes.

III. Action du cyanure de sodium

Nous avons utilisé uniquement le cyanure de sodium, l'ion K^+ possédant une toxicité propre non négligeable.

Nous avons recherché la dose maximum supportée par chacune des quatre espèces d'Ophryoglenidae, puis nous avons étudié les doses de cyanure de sodium supportées par ces mêmes espèces. Le tableau IV résume nos observations sur les infusoires chasseurs (stade théronte, le plus sensible aux rayons roentgen).

Le parallélisme observé entre la résistance des Ophryoglenidae au cyanure et aux rayons roentgen est remarquable. *O. pectans*, très sensible au rayons roentgen, supporte une faible concentration de NaCN alors

Tableau IV

Parallélisme entre la résistance des ophryoglenides (thérontes) aux rayons roentgen et au cyanure.

Espèce	*O. pectans*	*Deltopylum rhabdoides*	*O. atra*	*O. mucifera*
Dose léthale de rayons roentgen	600,000	750,000	900,000	1,050,000
Concentration maximale bien tolérée de NaCN	0.03 %	0.05 %	0.05 %	0.2 %

que *O. mucifera* très résistante à l'irradiation, vit normalement dans de très fortes concentrations de cyanure.

Nous avons vu que la résistance au rayonnement roentgen varie au cours du cycle. Les infusoires très à jeun pratiquement privés de réserve glycogénique sont les plus sensibles; ainsi, chez *O. atra* affamé, la mort survient après 750,000 r. Quand cette espèce est bien nourrie, la résistance monte à 950,000 r et l'infusoire supporte une solution à 0.1 % de NaCN. Chez *Deltopylum rhabdoïdes*, à deux divisions successives sans enkystement, la résistance monte à 1,050,000 r chez les individus en fin de seconde division, porteurs d'une importante réserve de glycogène. Ces derniers vivent dans une solution à 0.1 % de NaCN.

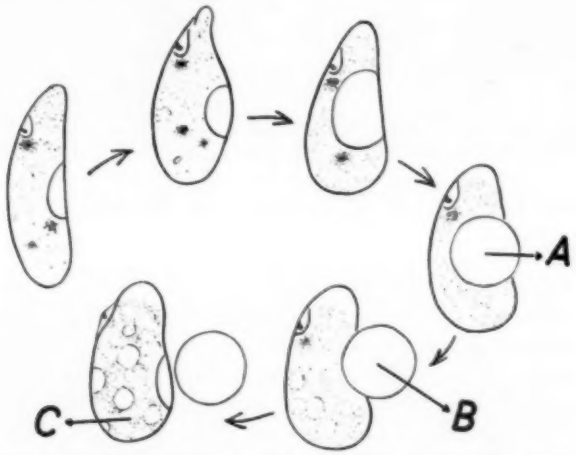

Fig. 11. Transformation subie par *O. pectans* (théronte) soumise à l'action de NaCN en solution à 0.05 %. A. Gonflement de la vacuole contractile, B. libération extrèmement ralentie des excrétats, C. vacuolisation du protoplasme. × 200.

Sous l'effet des concentrations de NaCN indiquées dans le tableau IV, le théronte se charge d'inclusions digestives, s'enkyste et se divise normalement. Si on élève la teneur en milieu NaCN jusqu'à 0.05 % l'infusoire (particulièrement O. pectans) tend à perdre, après 15 minutes environ, son pôle antérieur et sa vacuole contractile se gonfle à l'extrème. L'animal réussit parfois à éliminer les excrétats cellulaires mais son protoplasme se vacuolise peu à peu et au bout de deux heures, il éclate (fig. 11). Le processus léthal chez les autres espèces est un peu différent. Pour O. mucifera, qui a deux vacuoles contractiles, la vacuolisation du protoplasme

survient sans qu'il y ait blocage préalable de l'excrétion. On ne peut incriminer l'alcalinité des solutions de NaCN car les histiophages utilisés peuvent vivre dans un milieu pH variant entre 10 et 12 correspondant à celui du NaCN.

Il semblerait donc que le cyanure de sodium déclenche dans la cellule une série de modifications identiques à celles que provoquent les rayons roentgen.

Le tableau V montre d'autre part l'effet protecteur du NaCN sur les différents thérontes de nos Ophryoglenidae.

Tableau V

Doses de rayons roentgen immédiatement mortelles pour quatre Ophryoglenides, 1) dans H_2O, 2) dans une solution de NaCN — Effet protecteur du NaCN.

Espèce	*O. pectans*	*O. atra*	*O. mucifera*	*Deltopylum rhabdoides*
Dose léthale (en r) dans H_2O	600,000	900,000	1,050,000	750,000
Dose léthale (en r) après addition de la concentration maximum de cyanure tolérée.....	750,000	900,000	1,200,000	840,000

La protection que confère la présence du cyanure (0.05 %) est surtout marquée chez *O. pectans*.

IV. Action protectrice contre le rayonnement roentgen de diverses substances

Les travaux antérieurs de Bacq et Herve (1—7) ont permis de mettre en évidence la protection chimique contre les rayons roentgen offerte par certaines substances (nitrure de sodium, méthylamine, pyruvate de sodium, β mercapto-éthylamine, disulfure de bis-aminoéthane). Patt et ses coll. ont montré d'autre part l'effet protecteur de la cystéine (11).

Nous avons recherché systématiquement l'action de ces différents corps sur les infusoires irradiés.

Rappelons qu'il est nécessaire que ces corps soient présents au moment de l'irradiation. Aussi avons-nous procédé comme suit:

a) Recherche de la concentration de chaque substance tolérée par les organismes.

b) Introduction des infusoires dans la solution étudiée à la concentration tolérée.

c) Irradiation immédiate.

d) Transfert des organismes irradiés du milieu protecteur dans leur milieu aqueux habituel.

e) Observation de la survie.

Resultats

Les résultats de ces expériences sont résumés dans le tableau VI.

Tableau VI

Doses immédiatement mortelles (en roentgen) pour quatre espèces d'Ophryoglenides irradiées dans diverses solutions

Solutions étudiées	Concentration	*O. pectans*	*O. mucifera*	*O. atra*	*Deltopylum rhabdoides*
Témoin (H_2O)		600,000	1,050,000	900,000	750,000
Cystéine	0.01	660,000	1,050,000	900,000	900,000
Cystéine + Cyanure	0.2	1,200,000	1,200,000	1,050,000	900,000
(pH 7)	0.1				
Pyruvate de Na	0.2	750,000	1,110,000	900,000	750,000
Disulfure de aminoéthane [1]	0.2	750,000	1,200,000	750,000	750,000
β mercapto-éthylamine [1]	0.03	600,000	1,050,000	750,000	750,000
Méthylamine	0.2	600,000	1,050,000	900,000	750,000
Nitrure de Na	0.03	450,000	900,000	750,000	600,000

[1] Ces deux substances nous ont été fournies par les laboratoires de Recherches pharmaceutiques de la Société belge de L'Azote.

Nous avons vu précédemment le degré de protection offert par le cyanure de sodium. Aux concentrations utilisées, nous n'avons trouvé qu'une faible action protectrice de la cystéine. La combinaison cystéine-cyanure montre, par contre, une efficacité protectrice remarquable particulièrement pour l'Ophrioglène la plus sensible aux rayons roentgen: *O. pectans*. Le milieu cystéine-cyanure que nous avons employé étant à pH 7 et les quantités de cystéine et de cyanure étaient supérieures à celles tolérées par les Infusoires mis dans des solutions de cystéine et de cyanure prises séparément, la protection obtenue avec l'ion CN^- se trouverait donc renforcée par la molécule de cystéine.

La protection offerte par cette association se retrouve également au stade *trophonte* de *O. pectans* qui ne supporte normalement que 750,000 r et qui survit dans le milieu protecteur après 1,200,000 r. Les solutions de cyanure seules ne sont pas protectrices pour les trophontes.

Le disulfure de bis aminoéthane (1591 L) qui a la forme oxydée (S—S) de la mercapto-éthylamine (3) se montre aussi excellent protecteur de la cellule soumise aux rayons roentgen.

Les autres substances utilisées ne nous ont pas permis de mettre en évidence des phénomènes de protection.

V. Discussion

Les transformations morphologiques externes, après une irradiation mortelle de nos Infusoires, sont peu marquées; elles sont identiques pour toutes les espèces et pour chaque phase du cycle physiologique. On ne peut les considérer comme le facteur léthal déterminant de l'irradiation.

Par contre, si l'on compare les tableaux I et II, on constate que la sensibilité aux rayons roentgen d'*O. pectans* correspond à une faible teneur en hydrates de carbone de son protoplasme et que *O. mucifera*, dont le protoplasme est très chargé d'éléments hydrocarbonés, est plus radiorésistant. Les thérontes très affamés, dont le protoplasme est pauvre en hydrates de carbone, résistent relativement mal aux rayons roentgen alors que les individus de 2ème division prêts à sortir du kyste, à protoplasme riche en glucides (fig. 7) ont une résistance maximum aux rayons roentgen. Enfin, parmi les constituants protoplasmiques, la seule variation décelable enregistrée après irradiation est une diminution des hydrates de carbone.

Nous confirmons la radiorésistance et la cyanurorésistance des infusoires. Mais le parallélisme entre résistance au cyanure et résistance aux rayons roentgen (tableau IV) est si étroit qu'il suggère une association entre les deux phénomènes.

Quelques observations préliminaires faites sur une actinie (*Anemona sulcata*) nous ont montré qu'il faut 300,000 r pour les tuer; les actinies qui ont reçu 100,000 r meurent comme les témoins non irradiés. Or les actinies sont réputées être très résistantes au cyanure; de nombreuses espèces vivent parfaitement 15 jours dans une solution 0.25 % de KCN dans l'eau de mer, alors que les têtards de Grenouille sont tués en 15 à 20 minutes par une solution 0.01 % de NaCN, et que les Téléostéens marins meurent instantanément dans KCN 0.05 % (voir bibliographie dans HUNT, 9).

Ces observations prouvent que les infusoires et les actinies doivent utiliser l'oxygène au moyen de systèmes enzymatiques non sensibles au cyanure. Il est probable en outre que ces systèmes sont radiorésistants. Inversement, les systèmes sensibles au cyanure seraient aussi sensibles au rayonnement roentgen, ou, pour parler de façon plus précise, aux radicaux libres émis dans l'eau lors du passage des rayons roentgen.

L'action du cyanure est essentiellement de bloquer les métaux actifs (Cu, Fe) des enzymes oxydants, dont le jeu repose sur des échanges rapides d'électrons au niveau de ces métaux ($Fe^{++} \rightleftharpoons Fe^{+++}$). Or, les rayons roentgen oxydent les sels ferreux en sels ferriques, et ce fait a servi de base à maintes études des radiochimistes (voir symposium Faraday Society, Leeds, Avril 1952). Il est donc infiniment probable que cette étroite relation entre radiorésistance et cyanurorésistance a une signification biochimique profonde qu'il convient de préciser.

Le fait que le cyanure protège certaines Ophryoglènes contre la dose seuil mortelle de rayons roentgen ne peut infirmer l'hypothèse d'une combinaison radiorésistante enzyme + cyanure. En effet, cette protection est faible, et rien ne permet d'écarter une influence inhibitrice directe du cyanure sur l'action des radicaux libres. L'hypothèse d'une combinaison enzyme + cyanure radiorésistante n'exclut aucunement la possi-

bilité d'un effet direct, au départ, du cyanure sur les radicaux libres. Nous avons démontré que le disulfure de bis aminoéthane inhibe partiellement l'oxydation des sels ferreux par le rayonnement roentgen.

Ce travail a été réalisé à l'aide d'un subside du Ministère de l'Intérieur (Conseil supérieur de la Sécurité Civile) et grâce à l'intervention des Accords Culturels franco-belges qui ont accordé à Mademoiselle Mugard une bourse d'étude dans les laboratoires de l'Université de Liège.

RÉSUMÉ

Il existe un parallélisme étroit entre la résistance aux rayons roentgen et la résistance au cyanure de quatre espèces d'infusoires histiophages (*Ophrioglenidae*). La signification de ce fait est discutée.

Les recherches histochimiques chez les infusoires irradiés n'ont montré d'altérations que dans le domaine des hydrates de carbone. Le mélange cystéine + NaCN protège les Ophryoglènes contre la dose seuil mortelle de rayons roentgen; les autres protecteurs (cystéine seule, cyanure seul, pyruvate de sodium et disulfure de bis-amino-éthane) agissent plus faiblement et chez certaines espèces seulement.

SUMMARY

A close parallelism exists between the resistance to roentgen irradiation and the resistance to cyanide of four species of histophagous infusoria (Ophrioglenidae). The importance of this fact is discussed.

Histochemical studies on irradiated infusoria have shown changes only with regard to carbohydrates. The mixture of cysteine and NaCN is found to protect the Ophrioglenidae against the lethal threshold dose of roentgen rays. The other protectors (cysteine alone, cyanide alone, sodium pyruvate and β, β-aminoethyl disulphide) have a weaker action and on certain species only.

ZUSAMMENFASSUNG

Zwischen der Resistenz gegen Röntgenstrahlen und der Resistenz gegen Zyanid besteht bei 4 Gattungen von Aufgusstierchen (Ophrioglenidae) ein enger Parallelismus. Die Bedeutung dieser Tatsache wird diskutiert.

Histiochemische Untersuchungen an bestrahlten Aufgusstierchen haben Veränderungen nur im Gebiete der Kohlenhydrate gezeigt. Die Mischung Zystein + NaCN schützt die Aufgusstierchen gegen die tödliche Schwellendosis der Röntgenstrahlen. Die anderen Schutzmittel (Zystein allein, Zyanid allein, Natriumpyruvat und Disulpho-bisamino-aethan) sind viel schwächer und nur bei gewissen Gattungen wirksam.

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CENTRE ANTICANCÉREUX DE LYON (DIRECTEUR: PR. P. SANTY)

INDICATIONS ET RESULTATS DE LA ROENGENTHERAPIE DU CANCER BRONCHIQUE

(A propos de 140 Observations)

par

J. Papillon, R. Violland & M. Goyon

Il y a une quinzaine d'années, l'emploi de la Roentgenthérapie était pratiquement banni du traitement du cancer bronchique. Les Rayons Roentgen avaient une réputation d'inefficacité et de nocivité. Les complications infectieuses ou pleurales qu'ils déclenchaient trop souvent, les faisaient redouter à juste titre.

Depuis lors, les statistiques importantes de SHORVON, de Miss HILTON, de MM. HUGUENIN-LEMOINE & FAUVET, de DILLONE, de SMITHERS, de DOBBIE ont démontré l'intérêt fréquent de cette méthode appliquée avec sagesse, et provoqué un certain revirement dans l'appréciation du rôle possible de cette irradiation.

Ce nouveau courant d'opinion tient non seulement aux progrès réalisés dans le domaine technique et au perfectionnement de la balistique roentgenthérapique, mais surtout à une meilleure connaissance de la maladie grâce au développement simultané de l'endoscopie bronchique et de la chirurgie d'exérèse.

Affection rare, de diagnostic malaisé et tardif, le cancer bronchique est devenu une maladie fréquente, de diagnostic courant et de dépistage souvent précoce, auquel le clinicien comme le radiologue a le réflexe de songer en présence de multiples syndrômes radio-cliniques.

Malgré ces progrès de tous ordres, le problème de l'irradiation du cancer bronchique est très complexe, et il réserve à côté de satisfactions certaines, de sévères et fréquentes désillusions.

Cette irradiation se heurte à plusieurs ordres de difficultés. Sans parler du côté technique, sur lequel nous ne voulons pas insister ici, un des obstacles est représenté d'abord par le caractère protéiforme de

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cette affection. Son polymorphisme est aussi bien clinique, radiologique qu'évolutif, et malgré tous les efforts qui ont été faits, la classification histologique en épithéliomas épidermoïdes, indifférenciés et glandulaires ne traduit qu'une physionomie bien imparfaite de cette maladie aux aspects si variés que chaque cas possède presque sa marque personnelle.

Pour le Radiothérapeute, un élément particulier apparaît ici au premier plan: *c'est la Tolérance aux Rayons Roentgen;* or cette tolérance est extrêmement variable, et de plus, difficilement prévisible. Elle n'est pas fonction du volume de la tumeur. Certains sujets atteints de gros néoplasmes, tireront rapidement un effet favorable des irradiations sans le moindre mal des rayons; certains autres, au contraire, réagiront violemment par de l'oppression, des nausées, de la fièvre, même à des doses faibles. Les signes d'intolérance seront parfois si accusés, que très vite on devra abandonner la poursuite du traitement.

Cette mauvaise réceptivité sur laquelle on n'a pas assez coutume d'insister, n'est pas liée directement au type histologique. L'épithélioma epidermoïde réputé de radio-sensibilité moyenne aussi bien que l'épithélioma indifférencié en principe très radiosensible, peuvent se comporter, l'un et l'autre de manière très diverse.

Elle n'est pas fonction des conditions techniques d'irradiation. Elle se manifeste d'emblée, dès les premières séances, même à doses faibles.

Il ne s'agit pas d'une intolérance du médiastin, m s d'une susceptibilité de la tumeur bronchique elle-même, qui peut se manifester aussi bien pour de petites tumeurs radiographiquement inapparentes, que pour des cancers très évolués.

Cette particularité de certaines formes de cancer bronchique malaisée à prévoir, représente un des obstacles de ce traitement radiothérapique.

En présence de ce tableau complexe, quelle est la place de la Radiothérapie?

On a encore trop tendance à croire qu'une contrindication opératoire équivaut à la nécessité d'une irradiation. Ce principe est faux pour le cancer bronchique. Les Rayons Roentgen ne doivent pas être appliqués systématiquement et sans discernement à tous les cancers non chirurgicaux. Il faut savoir être parfois abstentionniste et la place de la Roentgenthérapie se situe entre la *chirurgie:* méthode curative, et l'*abstention thérapeutique:* formule négative.

A la Roentgenthérapie échoit, en principe, le rôle palliatif pour les formes encore traitables.

Mais l'irradiation elle-même peut se concevoir selon deux objectifs:

L'irradiation palliative qui n'a qu'un but symptômatique, avec objectifs modestes et à court terme.

L'irradiation à visée curative qui ne se propose pas véritablement de guérir, mais bien plutôt de faire l'effort suffisant pour distribuer en profondeur une dose cytolytique susceptible théoriquement d'obtenir une stérilisation locale de la tumeur et un effet appréciable sur la survie.

Ainsi, pour les malades non chirurgicaux, le Radiologiste devra choisir l'une des trois solutions suivantes:

Abstention,
Roentgenthérapie palliative,
Roentgenthérapie curative.

L'indication thérapeutique sera guidée par l'analyse du degré d'extension du cancer et, dans la mesure du possible, par l'appréciation de son potentiel évolutif. Elle tiendra également compte du terrain sur lequel se développe la tumeur et des conditions générales du patient.

Les contrindications de la roentgenthérapie

Une part importante des échecs du passé s'explique par l'irradiation de formes anatomocliniques que nous considérons actuellement comme au-dessus des ressources de cette méthode.

Pour refuser l'irradiation, des arguments d'ordre général et local sont invoqués.

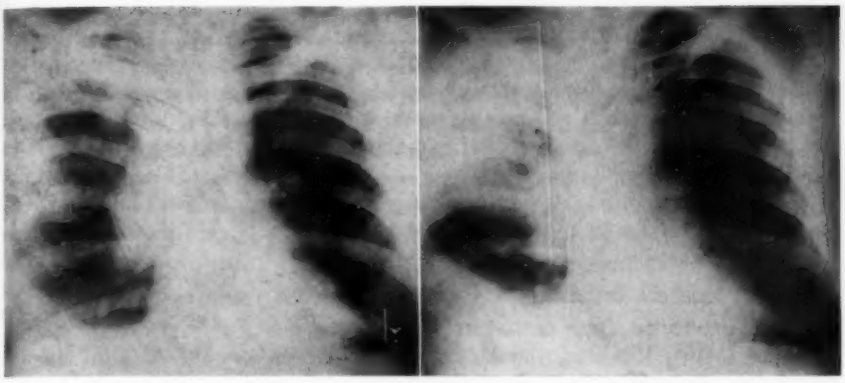
Chez les sujets cachectiques, épuisés par l'oppression et la toux, manifestement parvenus au stade ultime de leur évolution, de même que chez des sujets âgés de plus de *70 ans*, ce serait une erreur d'entreprendre une irradiation qui aggraverait la scène fonctionnelle et altérerait l'état général.

Sur le plan local, les cancers cavitaires, qu'ils soient précocement excavés ou secondairement suppurés, sont à rejeter, de même que les formes accompagnées d'un grand épanchement pleural, quelle que soit la nature de l'épanchement. Dans le premier cas, l'irradiation serait dangereuse, dans le second, elle sera rendue inefficace par l'existence d'un écran liquidien dont l'assèchement s'avèrera impossible.

Les cancers bronchiques associés à une tuberculose pulmonaire évolutive (HILTON) — ou compliqués de métastase viscérale — hépatique surtout, sont également des contrindications schématiques.

Dans le même cadre doivent être placés, comme l'indique HUGUENIN, les cancers massifs, ayant envahi une partie importante d'un poumon, tout un lobe par exemple. Ces tumeurs fréquentes autrefois, rares actuellement du fait du meilleur dépistage, sont vouées à un échec.

L'abstention paraît être également la solution de sagesse pour les cancers médiastino-pleuro-pulmonaires dont l'évolution très maligne se traduit par une extension rapide du hile vers la base, où se développent



a. b.

Fig. 1. a. Type de contrindication radiothérapique. Forme médiastino-pleuro-pulmonaire. Cliché pris dix jours avant l'admission à l'hôpital: tuméfaction hilaire avec grisaille axillaire et basale.

b. Radiographie pratiquée dix jours après la précédente. Développement rapide d'une évolution pleuro-pulmonaire, avec adénopathie sus-claviculaire.

simultanément un épanchement pleural et un ensemencement lymphatique du parenchyme. (Fig. 1 a & b.)

Dans tous ces cas, l'expérience, fondée surtout sur les échecs thérapeutiques d'il y a vingt ans, montre que l'irradiation sera non seulement inutile, mais nuisible. Si l'on cherche à se faire de la Radiothérapie du cancer bronchique une idée exacte, il convient de connaître ces contrindications et de savoir les respecter en pratique.

Indications de la roentgenthérapie palliative

Cette modalité d'irradiation n'a pour objectif qu'un effet symptômatique et une amélioration passagère. Ses indications sont nombreuses. Elles sont définies surtout d'après la forme anatomoclinique de la tumeur. D'une manière générale, entrent dans cette catégorie, les cancers rapidement envahissants et doués d'une haute malignité. Pour plus de clarté, on peut les grouper sous trois références principales:

1) *Les cancers bronchiques très adénogènes:*

La présence d'une adénopathie implique toujours un pronostic très sévère, même lorsqu'une exerèse chirurgicale demeure possible. Dans les formes radiothérapiques, cette notion conserve toute sa valeur; l'adénopathie peut être:

Hilaire et souvent si intimement liée à la masse néoplasique qu'il n'est pas toujours aisé de la dissocier radiologiquement de la tumeur elle-même.

Médiastinale, objectivée par un tableau complet de compression de la veine cave supérieure ou par des signes de localisation, tels qu'une atteinte récurrentielle ou une dysphagie par refoulement oesophagien.

Sus-claviculaire.

Épigastrique: dans ces deux derniers cas, le problème n'est plus local mais général, et l'attitude du radiologue doit être guidée par la présence de cette métastase.

2) *Les cancers bronchiques à symptômatologie prédominante:*

Nous groupons dans cette catégorie toutes les tumeurs qui se manifestent par des signes de souffrance fonctionnelle accentuée, qui impliquent l'intervention de la Roentgenthérapie dans un but sédatif:

L'hémoptysie par sa répétition constitue un signe alarmant, non seulement au point de vue psychologique, mais au point de vue pratique par l'affaiblissement de l'état général qu'elle entraîne.

La douleur est fréquente. Elle reconnait des types divers:

douleur des métastases osseuses,

douleur des cancers de l'apex, de type PANCOAST.

Toutes deux sont très rebelles et ne seront que très mal calmées par l'irradiation,

douleur thoracique profonde ou transfixiante des tumeurs envahissant le hile,

douleur périphérique osseuse ou ostéo-articulaire, accompagnant une ostéo-dystrophie ou une périostose engainante d'origine pneumique.

Ces deux variétés de manifestations algiques, souvent intolérables sont remarquablement améliorées et de manière durable par le traitement de la tumeur.

La dyspnée occupe parfois le centre du tableau clinique, et présente une telle acuité qu'elle simule une «bronchite asthmatiforme». Ces formes dyspnéisantes ne déterminent qu'un minimum de signes radiographiques et endoscopiques (Fig. 2). Il s'agit habituellement de tumeurs indifférenciées à évolution péribronchique engainante. Elles brûleront les étapes et la radiothérapie n'apportera qu'un soulagement éphémère sans ralentir le rythme évolutif de cette variété très maligne.

3) *Les cancers opérés de pneumonectomie:*

L'irradiation peut être employée à titre complémentaire, un mois ou un mois et demi après une intervention incomplète au cours de laquelle a dû être abandonné dans le médiastin postérieur, un ganglion inextirpable.

Les sujets, grands convalescents, ne sauraient supporter un traitement long et fatiguant orienté sur une région fragile où la cicatrisation et la résorption des exsudats sont encore récents.

Les *récidives* après pneumonectomies, qu'elles soient bronchiques, médiastinales, ganglionnaires ou pariétales, n'autorisent pas non plus de traitement intensif. Leur irradiation est uniquement palliative, comme d'ailleurs la plupart des récidives chirurgicales des tumeurs viscérales.

Dans ces divers cas, les conditions générales et le volume de la tumeur à irradier ne permettront pas de distribuer plus que quelques milliers «d'r.» à la peau, et l'on a fixé arbitrairement à environ *3,000 r./Tumeur*, la limite supérieure de radiothérapie palliative.

Indications de roentgenthérapie curative

Cette irradiation se propose de rechercher une stérilisation locale. Elle implique une dose profonde élevée, de l'ordre de 5 à 6,000 r. et n'est concevable que chez des sujets dont l'âge et l'état général soient convenables.

Comme nous l'avons dit, sa place se situe entre la chirurgie seule méthode radicale, et l'irradiation palliative. Ses frontières ainsi conçues sont théoriquement assez faciles à tracer.

D'une part, nous avons posé comme principe premier, l'inopérabilité, et tous nos patients ont été examinés dans le Service du Pr. SANTY et passés au crible de l'indication d'exérèse; ils représentaient tous, pour divers motifs, des refus d'intervention. Cette notion d'inopérabilité, qui doit être retenue dans l'analyse des résultats, reconnaît des causes générales telles que l'âge, une tare viscérale, ou même un refus opératoire formel du patient. Sur le plan local, les tumeurs non chirurgicales qui entrent dans ce cadre, sont celles qui sont implantées sur une bronche souche, trop près de la carina pour autoriser une exérèse satisfaisante, ou celles qui évoluant autour des gros troncs bronchiques, se sont révélées inopérables à un examen tomographique ou angiopneumographique, ou même à une thoracotomie demeurée exploratrice.

Les limites entre l'irradiation curative et l'irradiation palliative sont basées surtout sur le volume tumoral. Pour SHORVON, une lésion de plus de 6 cm de diamètre n'est plus du ressort du traitement curatif. Or on sait toute la difficulté qui existe à déterminer de manière suffisamment précise, les contours de la tumeur, lorsqu'elle empiète sur le médiastin, c'est dire le côté approximatif de cette définition. De plus, il convient d'apprécier le volume en fonction de l'histologie. En effet, la dose nécessaire pour obtenir la lyse totale d'un épithélioma malpighien est nettement supérieure à celle que devra recevoir pour obtenir le même effet, un épithélioma indifférencié. Il faut donc tenir compte de la radiosen-

sibilité de la tumeur dans l'appréciation du volume limite. Ainsi, des cancers indifférenciés, même volumineux, pourront dans les cas favorables, tirer un réel bénéfice d'une irradiation intensive, alors que seuls des cancers épidermoïdes de petite dimension seront justiciables de l'irradiation à dose curative.

Mais il existe malgré tout, des cas «limites» où cliniquement le choix entre méthode palliative et curative est délicat. La décision ne doit pas être prise d'emblée mais après une irradiation d'épreuve, d'une quinzaine de jours. Ce délai d'observation est nécessaire pour jauger la radiosensibilité de la tumeur, en définir le degré de malignité, et apprécier la tolérance générale aux Rayons.

L'ébauche d'une amélioration symptômatique, une sensation de mieux-être signalée par le patient, encourageront à entreprendre une irradiation intensive. Au contraire, une accentuation de l'asthénie de l'anorexie, une chute globulaire, inciteront à beaucoup de prudence et ne permettront pas de poursuivre le traitement au delà d'une dose palliative.

Résultats

De 1947 au 1er Avril 1951, nous avons irradié 140 malades atteints de cancer bronchique:

125 ont été traités par Roentgenthérapie seule.

15 avaient subi auparavant une pneumonectomie et ont dû être irradiés pour récidive ou à titre complémentaire après intervention incomplète.

Dans le Tableau I, nous avons réuni les caractéristiques des traitements employés et les contrôles histologiques ou macroscopiques qui ont pu être effectués dans 86 cas. Pour 54 malades, le diagnostic a été purement clinique. Dans un cas, l'examen cytologique des exsudats prélevés par aspiration a pu fournir la preuve de la nature épithéliomateuse de l'obstacle bronchique.

Tableau I

Nomenclature générale et classification histologique des cancers bronchiques traités par Roentgenthérapie

Nombre total des malades traités: 140

Traitements curatifs	50
Traitements palliatifs	75
Après pneumonectomies	15
Sans histologie ni thoracotomie	54
Avec histologie (Dr. GALY)	68
Avec thoracotomie exploratrice	18
Épidermoïdes	42
Indifférenciés	24
Adéno-carcinomes	2

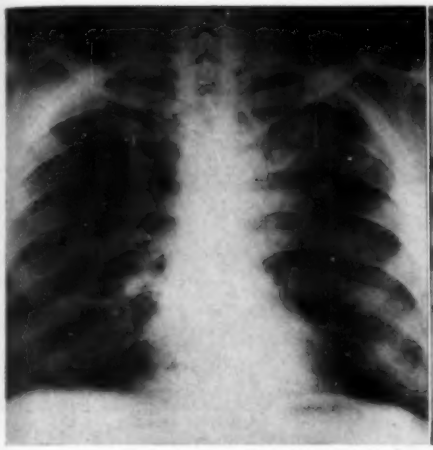


Fig. 2. Épithélioma indifférencié à développement surtout péri-bronchique de la bronche lobaire supérieure gauche. Cliniquement, forme dyspnéisante, avec chute rapide de l'état général représentant une indication limite d'irradiation palliative.

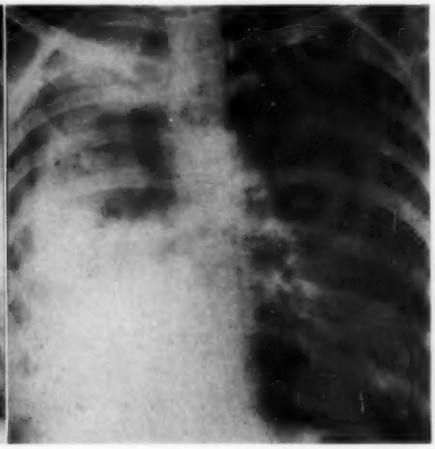


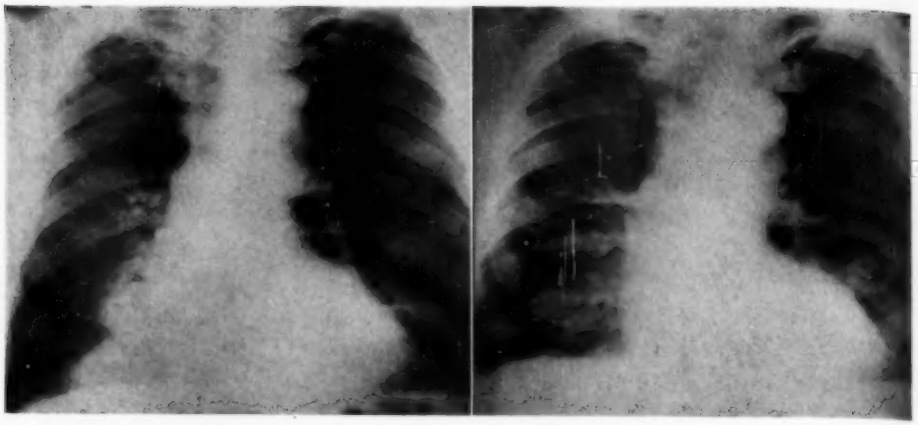
Fig. 3. Épithélioma à petites cellules de la bronche souche droite. Atélectasie du poumon droit et emphysème compensateur du poumon gauche. Traitement radiothérapique: 1,800 r./tumeur. Guérison clinique de plus de trois ans.

Si l'on exclue les récidives après pneumonectomie, on note que 50 cas ont pu être traités à dose curative entre 75 à dose palliative. La proportion est la même que celle de SMITHERS qui enrégistre 70 curatifs pour 95 palliatifs. Elle montre que si l'on sait respecter les contrindications totales, on trouve un nombre relativement élevé de patients dont les conditions générales et locales permettent l'application d'une dose de Radiothérapie de l'ordre de 5 à 6,000 r.

Parmi les traitements palliatifs, il existe un nombre égal d'épithéliomas malpighiens et d'épithéliomas indifférenciés, alors que dans les traitements intensifs, il n'y a que cinq indifférenciés pour seize malpighiens. Ainsi, apparaît nettement la malignité plus grande des formes indifférenciées, qui sont très adénogènes, très métastatiques, très vite au-dessus des possibilités d'un traitement radical.

Sept malades thoracotomisés ont pu recevoir un traitement complet, c'est dire que l'exploration chirurgicale ne constitue pas une gêne importante à l'entreprise radiothérapique. L'épanchement résiduel peut être rapidement tari et la cicatrice thoracique oblige seulement à surseoir pendant quelque temps à l'emploi de champs d'irradiation postérieurs.

Onze malades jugés cliniquement opérables, mais dont la thoracotomie ne fut qu'exploratrice n'ont pu recevoir qu'une irradiation modeste, en



a. b.

Fig. 4. a. Épithélioma indifférencié de la bronche lobaire inférieure droite avec atélectasie.

b. Après traitement roentgenthérapique 5,000 r./tumeur. Disparition du triangle atélectasique du lobe inférieur droit. Guérison clinique de trois ans.

raison le plus souvent d'une extension locale considérable. C'est une preuve du caractère insuffisant et trompeur de la documentation radio-clinique, même la plus consciencieuse, qui demeure souvent très en-dessous des constatations anatomiques, et rend particulièrement délicat l'emploi de la radiothérapie.

Tableau II

Étude de la survie en fonction du delai d'observation

	+ 6 mois		+ 1 an		+ 2 ans		+ 3 ans	
Curatifs	40/50	80 %	19/39	48 %	7/22	31 %	2/6	
Palliatifs	24/75	32 %	6/60	10 %	3/40	7 %	1/30	
Total	64/125	51 %	25/99	25 %	10/62	16 %	3/36	8 %

Pour calculer la survie moyenne, nous n'avons considéré que les 62 observations ayant un recul de deux ans.

Les 22 curatifs ont une survie moyenne post-therapeutique de seize mois.

Les 40 palliatifs ont une survie de sept mois.

Ces chiffres sont assez superposables à ceux fournis par BRIAN TAYLOR & WATERHOUSE dans un récent article du «Thorax», sur le pronostic du cancer bronchique, et à ceux présentés dernièrement par HUGUENIN, LEMOINE, FAUVET & BOURDIN.

L'analyse détaillée des survies montre que deux palliatifs sur trois meurent au cours des six premiers mois et que seulement un sur dix dépasse un an. Il n'y a pas de prolongation appréciable de la vie.

Une influence sur la survie nécessite l'application d'une dose importante. Dans les formes traitées radicalement, un cas sur deux dépasse un an, et un sur trois excède deux ans. Ces chiffres d'ailleurs, ont une valeur très relative en raison de l'effectif global insuffisant et de la très grande dissemblance des tumeurs traitées.

Parmi nos survivants actuels, six dépassent deux ans et trois dépassent trois ans. De ces derniers, deux sont des épithéliomas indifférenciés, dont un à petites cellules. Le troisième était porteur d'une tumeur péribronchique impossible à biopsier, mais dont les caractères morphologiques inclinent à penser qu'il s'agissait probablement d'une forme indifférenciée.

HUGUENIN, dans sa statistique de 1950, reconnaît que sa plus longue survie de soixante-quatre mois a trait à un épithélioma à petites cellules, et considère ce cas comme exceptionnel.

Sans vouloir tirer aucune conclusion définitive, on doit retenir toutefois, que les cancers indifférenciés n'ont pas tous la haute malignité qu'on leur prête habituellement. Certaines formes polypoïdes, atypiques ou à petites cellules, paraissent douées d'un faible potentiel adénogène ou métastatique, en même temps que d'une haute radiosensibilité puisque les contrôles endoscopiques démontrent leur fonte à des doses profondes relativement modérées. Ces tumeurs, d'ailleurs rares, représentent d'excellentes indications de radiothérapie.

Malheureusement ces formes relativement radio-curables sont rares. La plupart des tumeurs indifférenciées font la preuve rapide de leur grande malignité. Nous avons pu vérifier l'une d'elles:

Homme de 50 ans, porteur d'un épithélioma indifférencié de la bronche lobaire moyenne. Traitement radiothérapique du 13/2 51 au 14/4 51: 5,200 r./tumeur. On assiste à la disparition de la tumeur endobronchique et de l'atélectasie. Exitus le 19/6 51.

L'autopsie a montré la stérilisation de la bronche moyenne où il n'existait plus trace de cancer, mais la mort était due à un hémopéricarde dû à la rupture d'un ganglion néoplasique à la fois dans la veine cave supérieure et dans le péricarde.

Le comportement des cancers épidermoïdes est tout autre. Leur sensibilité plus faible rend leur stérilisation locale malaisée. Des doses très élevées doivent être employées, qui peuvent, comme l'a dit HUGUENIN favoriser une nécrose centrale de la tumeur, génératrice parfois d'hémoptysies foudroyantes. Nous avons observé trois fois cet accident, et pu contrôler une fois l'état de la tumeur:

Homme de 54 ans, porteur d'un épithélioma épidermoïde spino-cellulaire de la bronche souche gauche, à 3 cm de la carina.

Le traitement radiothérapique comporta 7,000 r./tumeur. Peu après la fin des irradiations, le malade mourut d'une hémoptysie massive.

L'examen anatomo-pathologique montra un foyer nécrotique à l'emplacement de la tumeur, avec un vaisseau pulmonaire béant dans l'ulcération.

L'examen histologique de la pièce ne révèla aucune tumeur organisée ou en évolution, mais au milieu de foyers en pleine cytolyse, quelques formations en tourbillon évoquant des globes cornés.

Ces complications dramatiques sont rares, mais elles démontrent que les doses carcinolytiques utilisables pour les cancers épidermoïdes sont voisines des doses de nécrose. Cependant, la sensibilité et le rythme évolutif de cette variété de tumeur sont tels que des résultats appréciables sur la survie peuvent être obtenus dans nombre de cas.

Conclusions

De cette statistique, on peut retenir les enseignements suivants:

1) Un nombre important de malades atteints de cancer bronchique tireront un bénéfice certain de la Radiothérapie. Ce traitement, à condition de savoir en respecter les indications, ne comporte qu'un minimum d'incidents et de risques.

2) Les malades à irradier se classent en deux groupes:

Les uns porteurs de tumeurs très évoluées ou très évolutives, ne présenteront, le plus souvent, qu'une amélioration fonctionnelle passagère, sans modification appréciable de la survie, après un traitement qui n'aura pu être que palliatif.

L'autre groupe, moins nombreux, sera justiciable d'une irradiation intense et promis, dans les formes favorables, à des survies importantes.

3) Ces résultats paraissent dépendre en une certaine mesure, de la variété histologique.

Les cancers épidermoïdes ont une évolution spontanée relativement lente. Ils sont, par certains points, comparables aux cancers de l'hypopharynx, et comme eux, leur stérilisation sera difficile, mais, même en l'absence d'une guérison anatomique, l'effet palliatif pourra se traduire par des rémissions de longue durée.

Les cancers indifférenciés sont doués d'une malignité telle que très souvent ils brûlent les étapes et ne sont justiciables que d'un traitement palliatif. Par contre, certaines formes encore localisées, bénéficiant de la haute radio-sensibilité de cette variété, pourront parfois être stérilisées localement et donner de véritables guérisons durables.

Ces notions doivent être retenues dans la définition des indications respectives de la Radiothérapie et de la Chirurgie.

4) Il ne serait être question de faire un parallèle entre les résultats de ces deux méthodes, car elles ne s'adressent pas aux mêmes types de malades. Si la radiothérapie évite pratiquement la mortalité immédiate, elle ne peut faire état que d'un nombre très restreint de succès de trois ans.

Cependant, on doit reconnaître qu'une connaissance plus parfaite des possibilités de ces deux techniques permettra une orientation meilleure des indications surtout dans les cas d'opérabilité limite, où des facteurs généraux et des facteurs psychologiques peuvent plaider en faveur de l'une ou l'autre méthode.

5) On pourrait être tenté de combiner la Radiothérapie à la Chirurgie. Cette formule, théoriquement satisfaisante est d'une réalisation difficile. L'irradiation préparatoire ne rend pas opérable ce qui ne l'était pas et l'on se heurte à une règle générale de carcinologie, qui trouve ici sa vérification.

Quant à la Roentgenthérapie post-opératoire, sa tolérance est médiocre, voire mauvaise chez un convalescent de pneumonectomie. Il est rare que l'on puisse atteindre une dose profonde carcinolytique; tout au plus pourra-t-on être utile dans les cancers indifférenciés dont l'essaimage lymphatique peut être momentanément stoppé par l'irradiation, mais d'une manière générale, il ne semble pas que l'on puisse entrevoir dans cette association radio-chirurgicale, la solution pour l'avenir.

RÉSUMÉ

D'après une statistique de 140 cancers bronchiques traités par les Rayons Roentgen au Centre Anticancéreux de Lyon, les auteurs précisent, en fonction de l'état général, des conditions locales et des données de l'examen histopathologique, les contra-indications de cette méthode et les indications respectives de l'irradiation curative et palliative. Ils soulignent le polymorphisme de cette affection et la difficulté de traiter cette variété de patients dont la tolérance à la radiothérapie est très diverse. Bien que tous aient été jugés inopérables, 10 malades sur 62 ont survécu plus de deux ans et 3 sur 36 sont guéris depuis plus de trois ans. La connaissance de ces résultats doit permettre une meilleure orientation de la thérapeutique dans les tumeurs d'opérabilité discutable et dans celles où l'abstention est une règle de sagesse.

SUMMARY

Following a statistical survey of 140 cases of bronchial cancer treated by roentgen rays at the Anti-Cancer Centre at Lyon, the authors summarize in terms of the general state, local condition and data from the histo-pathologic examination, the contra-indications for the method as well as the indications for curative and palliative irradiation, respectively. They emphasize the varying nature of this condition and the difficulty in treating those types of patient in which the tolerance to radiotherapy is very diverse. In spite of the fact that all might have been considered inoperable, 10 cases out of 62 have survived more than two years and 3 out of 36 have had more than a three years cure. The appreciation of these results should permit of a better exhibition of therapy in cases of tumours doubtfully operable as well as in those in which expectancy is a matter of discretion.

ZUSAMMENFASSUNG

Als Resultat einer Statistik über 140 Bronchialkarzinome, die im Centre Anticancéreux in Lyon röntgenbehandelt worden sind, präzisieren die Verf. unter Berücksichtigung des Allgemeinzustandes sowie der lokalen und patologisch-anatomischen Befunde die Kontraindikationen dieser Methode und die Indikationen für kurative und palliative Röntgenbestrahlung. Sie heben den Polymorphismus dieser Krankheit sowie die Schwierigkeit hervor, derartige Patienten mit sehr verschiedener Toleranz gegenüber der Strahlentherapie zu behandeln. Obwohl alle als inoperabel beurteilt worden sind, haben 10 von 62 Kranken mehr als zwei Jahre gelebt und 3 von 36 sind seit mehr als 3 Jahren geheilt. Die gewonnenen Resultate geben einen besseren Überblick über die Behandlungsmöglichkeiten der Fälle mit zweifelhafter Operabilität sowie der als inoperabel betrachteten Fälle.

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ACTA RADIOLOGICA

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On behalf of the James Picker Foundation, the National Research Council announces the continued availability of Grants in Radiological Research. The Council has been designated as the administrative and scientific advisory body to the Foundation. Applications are reviewed by the Committee on Radiology of the Council's Division of Medical Sciences. Final determination of awards is made by the Board of Directors of the Foundation upon recommendation of the Committee, and the Council is responsible for administration of funds.

Grants in Radiological Research are designed to encourage research offering promise of improvement in radiological methods of diagnosis or treatment of disease. The Foundation has expressed particular interest in the support of research oriented toward diagnostic aspects of radiology. It has specifically requested that none of its funds be used to subsidize the development of radiological equipment. Grants are not restricted to institutions within the United States. Applications for grants for the fiscal year 1953—1954 must be postmarked on or before November 30, 1952.

Further details and application blanks may be obtained from the Secretary, Division of Medical Sciences, National Research Council, 2101 Constitution Avenue, N. W., Washington 25, D. C.

Announcement of the Fellowships in Radiological Research available under the program of the Foundation has been issued separately. Inquiries should be addressed to the Fellowship Office of the National Research Council.

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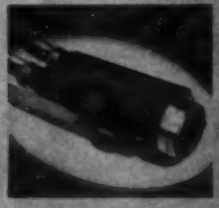

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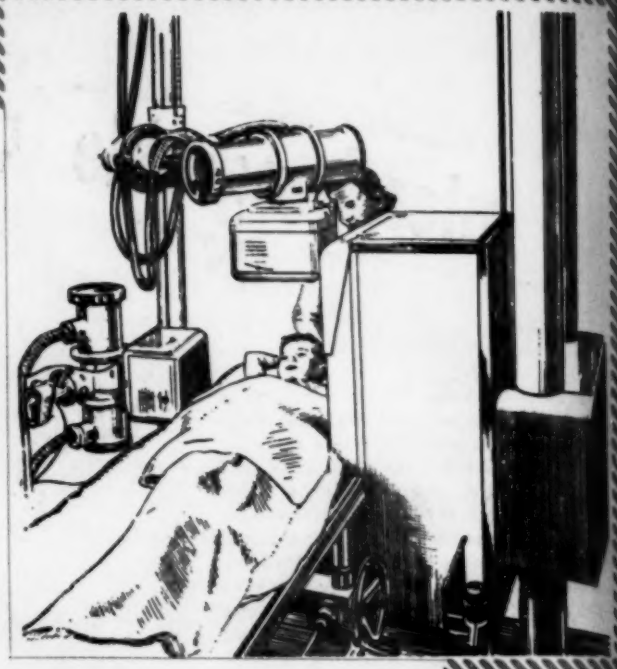

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